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Circular No. 77 - Measurement of Irrigation Water

George D. Clyde

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UTAH STATE AGRICULTURAL COLLEGE

UTAH AGRICULTURAL EXPERIMENT STATION

MEASUREMENT OF IRRIGATION WATER

GEORGE D. CLYDE

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Water is the limiting factor in Utah's agricultural development. In spite of its admitted value the farmer knows less about the measurement of water than about any of the other commodities which he handles. He knows how to measure his land, his crops and his cattle, but he has little conception of how to measure his most valuable asset, viz., irrigation water. The importance of water measurement is not appreciated until the water-supply becomes over-appropriated and users begin interfering with each other's rights. Expensive litigation, which always follow controversies over water, is gradually convincing the farmer that water should be measured as carefully as beets, grain, sugar, coal, flour, or any other commodity which he uses.

The building of storage reservoirs for utilizing flood water and winter flow has brought into use new irrigation conditions which depend for their success on the measurement of water. The storage reservoir may be considered a bank in which the farmer deposits, instead of gold, silver, or currency, a certain quantity of water which he will use later for irrigation. He draws this water from storage as he needs it, the same as he draws his money from the bank. To protect the various rights in the reservoir the water must be measured in and out.

Even if grown on the same soil, different crops require different amounts of water. Different soil types require different amounts of water for the same crop. For the farmer to utilize water economically it is necessary that he know how much water to apply and how to measure the amount of each application.

The farmer is rapidly recognizing the need and value of water

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measurement, as is evidenced by the many inquiries that come to the Utah Agricultural Experiment Station for information concerning this subject.

The object of this circular is to present in simple language the elements of water measurement. The circular includes a statement of the fundamental units used and a discussion of the common methods of water measurement, together with the tables and formulas necessary to practical use. The material is in the main simply a compilation of state and federal publications on water measurement. Since this publication is written to meet the needs of practical irrigators and water users, technical language is avoided whenever possible.

DEFINITION OF TERMS USED IN WATER MEASUREMENT

There are two conditions under which water is measured: (1) Water at rest and (2) water in motion.

Water at rest, i. e., in reservoirs, ponds, soil, and tanks, is measured in units of volume as the gallon, cubic foot, acre-foot, and acre-inch.

Water in motion, i.e., flowing in rivers, canals, pipe lines, ditches, and flumes, is expressed as rates of flow, i.e., gallons per minute (g.p.m.), cubic feet per second (c.f.s.), acre-feet per day, acre-inches per hour, and miner's inches.

It is important that the distinction between a unit of volume and a unit rate of flow be kept in mind. For instance, a cubic foot is a definite quantity of water such as would be held in a container 1 foot wide, 1 foot broad, and 1 foot deep, whereas a cubic foot per second is a flow which would fill the cubic foot container once every second as long as the flow continued.

Acre-foot—An acre-foot is a volume of water sufficient to cover an acre 1 foot deep, or 43,560 cubic feet.

Acre-inch—An acre-inch is a volume sufficient to cover an acre 1 inch deep. It is equal to one-twelfth of an acre-foot, or 3630 cubic feet.

Cubic foot per second (c.f.s.)—This unit represents an exact and definite quantity of water. It is the equivalent of a stream 1 foot wide and 1 foot deep, flowing at the rate of 1 foot per second.

Gallon per minute (g.p.m.)—This is a definite quantity of water. It is the equivalent of a stream which would fill a gallon measure once each minute of time.

Miner's Inch—Miner's inch is a rate of flow. It is a variable unit having different meanings in different states. The Utah miner's inch is a quantity of water flowing freely through an opening 1 inch square, the center of which is 4 inches below the surface of the water standing above the opening. It is equivalent to a flow of 9 gallons per minute or 1/50 of a cubic foot per second. **The miner's inch is not a stream of water 1 inch deep and 1 inch wide regardless of pressure.** The miner's inch is a convenient unit for measuring small streams, but where flow is 1 cubic foot per second or greater the most common unit is cubic feet per second.

The cubic foot per second (c.f.s.) is generally accepted as the standard unit of measurement expressing the rate of flow. Pump manufacturers have always expressed their pump capacities in gallons per minute; therefore, this unit is still used in discussing flow from wells or pumps. Several other units are used to express rate of flow, but they differ from those defined above only in the time interval. For quick conversion from one unit to another without calculation Figure 1 is included. The top scale on Figure 1 is cubic feet per second. To change from cubic feet per second to any other unit, follow the division line vertically downward until it intersects the scale of the unit desired. Thus, 5 c.f.s. equals 2250 g.p.m., 300 cubic feet per minute, 10 acre-feet per day, 5 acre-inches per hour, etc.

SOME CONVENIENT RELATIONS

Some convenient relations between the units of flow are:

1. 1 cubic foot per second (c.f.s.)=450 gallons per minute (g.p.m.)
   1 cubic foot=7.5 gallons (Approximate)
   60 seconds=1 minute
   7.5x60=450 gallons per minute (g.p.m.)

2. 1 cubic foot per second=1 acre-inch per hour (Approximate)
   3600 seconds=1 hour
   1 c.f.s.=3600 cubic feet per hour
   1 acre-foot=43,560 cubic feet
   1 acre-inch=1/12x43,560=3630 cubic feet
   Therefore, 1 c.f.s=1 acre-inch per hour (Approximate)

3. 1 cubic foot per second=2 acre-feet in 24 hours (Approximate)
   1 c.f.s.=3600 cubic feet per hour
   24x3600=86,400 cubic feet
   1 acre-foot=43,560 cubic feet; 86,400÷43,560=1.9834
   Therefore, 1 c.f.s.=2 acre-feet in 24 hours (Approximate)

EXAMPLES IN THE USE OF CONVENIENT RELATIONS

Examples of how to use the relations given (See Table 1 and Fig. 1) are:

1. Jones has a pump which discharges 450 g.p.m. If he spends 60 hours in irrigating a 10-acre orchard, what average depth in inches does he apply? (Note that the size of the stream, the length of time it is to be applied, and the area are given.)
   450 g.p.m.=1 c.f.s.
   1 c.f.s. for 1 hour=1 acre-inch
   1 c.f.s. for 60 hours=60 acre-inches
   These 60 acre-inches are to be spread uniformly over 10 acres. The average depth, therefore, is **6 inches**. (Answer)

2. How long will it take to apply a 6-inch irrigation uniformly over a 15-acre tract if the size of irrigation stream is 3 c.f.s.?
   15x6=90 acre-inches to be applied
   3 c.f.s=3 acre-inches per hour
   90/3=**30 hours** (Answer)

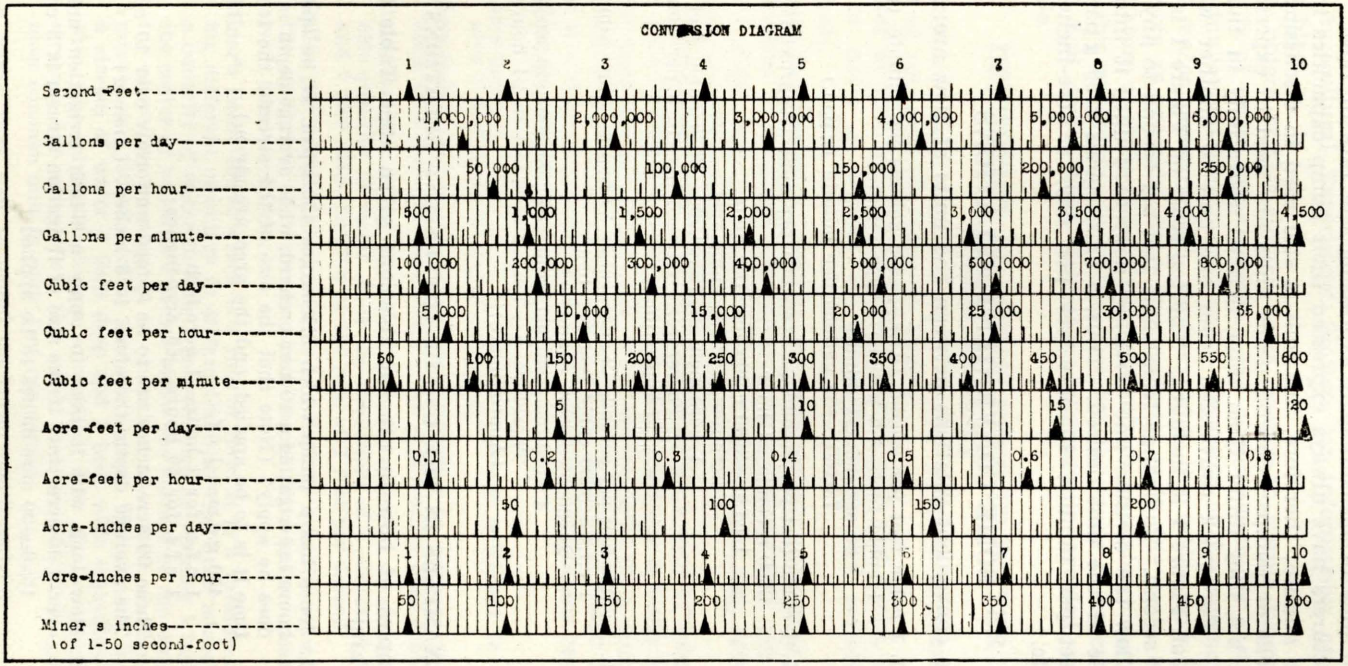

Fig. 1. Conversion diagram for finding equivalent rates of flow

3. How much land will a continuous flow of 15 c.f.s. cover in 4 months if each acre must have an average depth of 3 feet?
   1 c.f.s.=2 acre-feet per day
   15 c.f.s=30 acre-feet per day
   120x30=3600 acre-feet (Total area)

   Each acre requires 3 acre-feet. Total area$=\frac{3600}{3}=$**1200 acres** (Answer)

4 A flow of 5 c.f.s. is equal to how many acre-inches per day? (See Fig. 1) Look vertically under 5 c.f.s. and read answer (120 acre-inches) on scale of acre-inches per day.

METHODS OF WATER MEASUREMENT

The devices commonly used for measuring irrigation water are: (1) Weirs, (2) orifices, (3) rating flumes, (4) Venturi flumes, and (5) volume meters. Of these, weirs, orifices, Venturi flumes, and rating flumes are most commonly used by the farmer.

WEIRS

Terms Used.—The following terms are used in connection with weirs:

Weir—A bulkhead placed across a ditch or stream with an opening cut in the top through which the water is allowed to pass. The opening is called the weir notch

Weir Pond—The portion of the ditch immediately upstream from the weir

Weir Crest—The bottom of the weir notch

Head-on-Crest—The depth of water flowing over the weir crest and is measured at some point in the weir pond

Sharp-crested Weir—A weir having thin-edged crest and sides such that the overflowing water touches the crest at only one point

End Contraction—The horizontal distance from the end of the weir crest to the side of weir pond

Bottom Contraction—The vertical distance from the weir crest to the bottom of the weir pond

Weir Scale or Gage—The scale fastened on side of weir or on stake in weir pond to measure head-on-crest.

Weirs may be divided into two general classes: (1) Sharp-crested weirs and (2) broad-crested weirs. The sharp-creasted weir is discussed in this circular. The sharp-crested weir may again be divided into weirs with end contractions and weirs without end contractions. A weir without end contractions (called a suppressed weir) is one in which the crest length equals the width of the weir pond.

Weirs may be built as stationary structures, or they may be made portable. The portable weirs are usually made of wood or sheet steel and are placed in the ditch where a measurement is desired. Figure 2 shows a portable weir made of steel. Figure 3 shows a wooden portable weir installed. The stationary structures may be

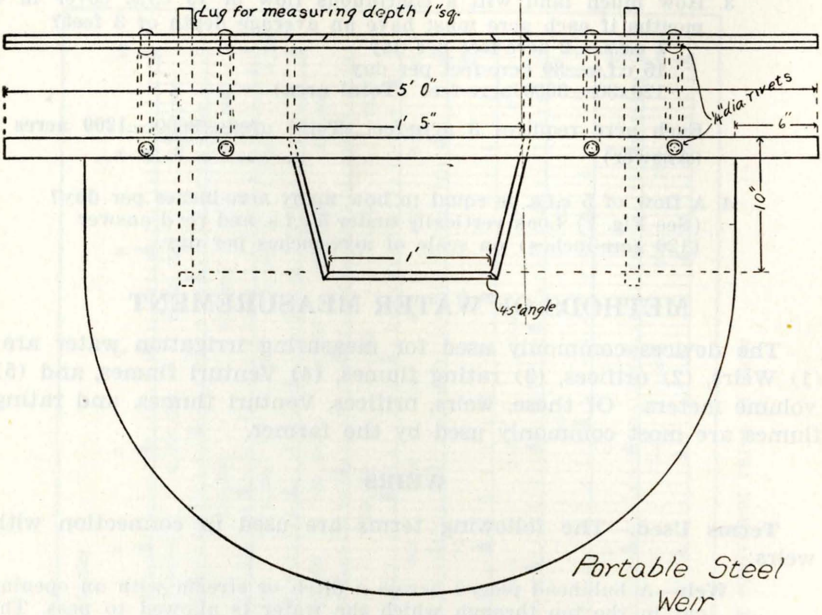

Fig. 2. Portable steel weir

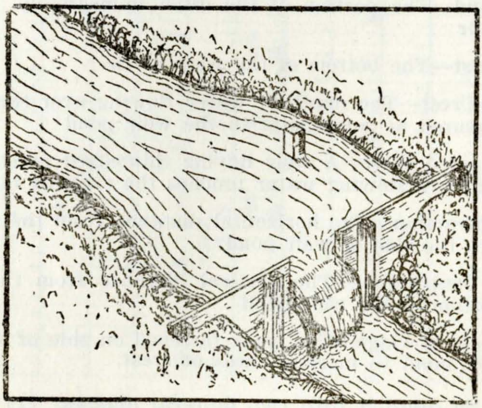

Fig. 3. Weir notch and bulkhead in weir pond

built of wood, steel, or concrete. In the wood and concrete structures the notch is usually faced with a metal strip which constitutes the sharp crest. Figure 4 shows the use of angle iron for the crest of a concrete weir.

Where the weirs are built as stationary construction, a weir box is commonly used. The bulkhead is placed in the lower end of the box and the upper end constitutes the weir pond. To permit cleaning the weir pond the weir bulkhead should be made removable.

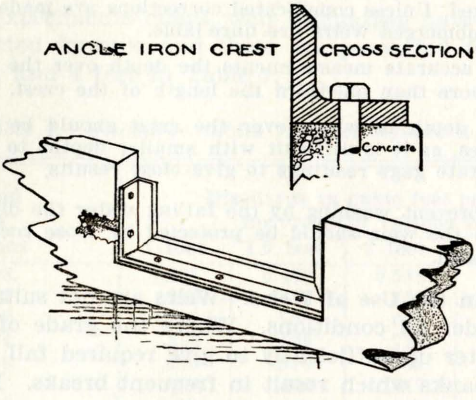

Fig. 4. Angle iron crest in rectangular weir

General Requirements for Proper Setting and Operating Weirs.—

(1) The weir should be set at the lower end of a long pool sufficiently wide and deep to give an even, smooth current with a velocity of approach of not over 0.5 foot per second, which means practically still water.

(2) The center line of the weir box should be parallel with the direction of the flow.

(3) The face of the weir should be perpendicular, i.e., leaning neither upstream nor downstream.

(4) The crest of the weir should be level so the water passing over it will be of the same depth at all points along the crest and sharp-crested so that the overfalling water touches the crest at only one point.

(5) The distance of the crest above the bottom of the pool should be about three times the depth of water flowing over the weir crest; the sides of the pool should be at a distance from the sides of the crest not less than twice the depth of the water passing over the crest.

(6) The gage or weir scale may be placed on the upstream face of the weir structure and far enough to one side so that it will be in comparatively still water, as shown in Figure 3, or it may be placed at any point in the weir pond or box, so long as it is sufficiently above the weir to be free from the downward curve of the water as it passes over the weir crest. The zero of the weir scale or gage should be placed level with the weir crest. This may be done with an ordinary carpenter's level, or where greater refinement is desired, with an engineer's level.

(7) The measurement of the head or depth of water on the crest may be made by placing a carpenter's rule or scale on a lug placed to the side of the weir notch or on a stake placed in the weir pond 4 or 5 feet above the weir. The lug or stake must be placed level with the weir crest.

(8) The crest should be placed high enough so the water will fall freely below the weir, leaving an air space under the overfalling sheet of water. If the water below the weir rises above the crest this free fall is not possible, and the weir is then said to be sub-

merged. Unless complicated corrections are made, measurements on submerged weirs are unreliable.

(9) For accurate measurements the depth over the crest should be no more than one-third the length of the crest.

(10) The depth of water over the crest should be no less than 2 inches, as it is difficult with smaller depths to get sufficiently accurate gage readings to give close results.

(11) To prevent washing by the falling water the ditch downstream from the weir should be protected by loose rock or by other material.

Limitations in the Use of Weirs.—Weirs are not suitable for measuring water under all conditions. Where the grade of ditch is flat, backing the water up sufficiently to give required fall over the weir, requires high banks which result in frequent breaks. In flat ditches it is difficult to keep the weir from becoming submerged.

Where the stream carries much silt the weir is not practical as a means of water measurement. Reducing the velocity of the water in the weir pond causes a deposition of silt which fills up the pond and destroys the proper conditions of flow for a weir measurement. This difficulty may be partly overcome by making the weir crest removable so that the weir pond may be cleaned out frequently.

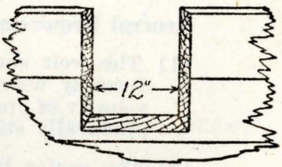

Fig. 5. Rectangular weir with end contractions

Rectangular Weir[1].—The rectangular weir, named from the shape of its notch, is the oldest weir in use. Its simplicity of form, ease of construction, and accuracy make it a desirable device for measuring water. Because of the vertical ends and the complete end contractions, the middle part of the weir discharges slightly more water than the same length of weir near either end, whereas the trapezoidal weir with sloping ends is commonly believed to discharge the same amount of water near either end as it does in the middle. However, extensive experiments recently conducted by the United States Department of Agriculture, indicate that four times the discharge over a 1-foot trapezoidal weir is greater than the discharge, under the same "head", over a 4-foot trapezoidal weir[2]. Upon the

[1]Israelsen, O. W. "Practical Information on the Measurement of Irrigation Water". Utah Agr. Exp. Sta. Cir. 36 (1919)

[2]Cone, V. M. "Construction and Use of Farm Weirs". U.S.D.A. Farmers' Bul. 813 (1917). It is concluded by Mr. Cone, in immediate charge of the work cited, that the discharge is not strictly proportional to the length over either of the weirs under consideration, but that it is most nearly so with the trapezoidal weir. Further experiments show that to make a weir, the discharge of which would be strictly proportional to the length, would require the construction of curved sides approaching the vertical with increase in distance above the crest.

basis of the experiments cited[3], weir discharges have been computed from a corrected formula and these are presented for crest lengths of 1, 1.5, 2, 3, and 4 feet in Table 1.

Table I.—Discharge tables for rectangular weirs[4]

Head in Feet	Head in Inches	Discharge in cubic feet per second for crests of various lengths				
		1 foot	1.5 feet	2 feet	3 feet	4 feet
0.20	2 3/8	0.291	0.439	0.588	0.887	1.19
.21	2 1/2	.312	.472	.632	.954	1.28
.22	2 5/8	.335	.505	.677	1.02	1.37
.23	2 3/4	.358	.539	.723	1.09	1.46
.24	2 7/8	.380	.574	.769	1.16	1.55
.25	3	.404	.609	.817	1.23	1.65
.26	3 1/8	.428	.646	.865	1.31	1.75
.27	3 1/4	.452	.682	.914	1.38	1.85
.28	3 3/8	.477	.720	.965	1.46	1.95
.29	3 1/2	.502	.758	1.02	1.53	2.05
.30	3 5/8	.527	.796	1.07	1.61	2.16
.31	3 3/4	.553	.836	1.12	1.69	2.26
.32	3 13/16	.580	.876	1.18	1.77	2.37
.33	3 15/16	.606	.916	1.23	1.86	2.48
.34	4 1/16	.634	.957	1.28	1.94	2.60
.35	4 3/16	.661	.999	1.34	2.02	2.71
.36	4 5/16	.688	1.04	1.40	2.11	2.82
.37	4 7/16	.717	1.08	1.45	2.20	2.94
.38	4 9/16	.745	1.13	1.51	2.28	3.06
.39	4 11/16	.774	1.17	1.57	2.37	3.18
.40	4 13/16	.804	1.21	1.63	2.46	3.30
.41	4 15/16	.833	1.26	1.69	2.55	3.42
.42	5 1/16	.863	1.30	1.75	2.65	3.54
.43	5 3/16	.893	1.35	1.81	2.74	3.67
.44	5 1/4	.924	1.40	1.88	2.83	3.80
.45	5 3/8	.955	1.44	1.94	2.93	3.93
.46	5 1/2	.986	1.49	2.00	3.03	4.05
.47	5 5/8	1.02	1.54	2.07	3.12	4.18
.48	5 3/4	1.05	1.59	2.13	3.22	4.32
.49	5 7/8	1.08	1.64	2.20	3.32	4.45
.50	6	1.11	1.68	2.26	3.42	4.58
.51	6 1/8	1.15	1.73	2.33	3.52	4.72
.52	6 1/4	1.18	1.78	2.40	3.62	4.86
.53	6 3/8	1.21	1.84	2.46	3.73	4.99
.54	6 1/2	1.25	1.89	2.53	3.83	5.13
.55	6 5/8	1.28	1.94	2.60	3.94	5.27
.56	6 3/4	1.31	1.99	2.67	4.04	5.42
.57	6 13/16	1.35	2.04	1.74	4.15	5.56
.58	6 15/16	1.38	2.09	2.81	4.26	5.70
.59	7 1/16	1.42	2.15	2.88	4.36	5.85
.60	7 3/16	1.45	2.20	2.96	4.47	6.00
.61	7 5/16	1.49	2.25	3.03	4.59	6.14
.62	7 7/16	1.52	2.31	3.10	4.69	6.29
.63	7 9/16	1.56	2.36	3.17	4.81	6.44
.64	7 11/16	1.60	2.42	3.25	4.92	6.59

[3]Cone, V. M. "Flow through Weir Notches with Thin Edges and Full Contractions". In *Jour. Agr. Rsch.* 5: 1051-1113 (1916)

[4]Computed from the formula $Q = 3.247\, lH^{1.48} - \frac{0.566\, l^{1.8}}{1+2\, l^{1.8}} H^{1.9}$.

Table 1—(Continued)

Head in Feet	Head in Inches	Discharge in cubic feet per second for crests of arious lengths				
		1 foot	1.5 feet	2 feet	3 feet	4 feet
.65	7 13/16	1.63	2.47	3.32	5.03	6.75
.66	7 15/16	1.67	2.53	3.40	5.15	6.30
.67	8 1/16	1.71	2.59	3.47	5.26	7.05
.68	8 3/16	1.74	2.64	3.56	5.38	7.21
.69	8 1/4	1.78	2.70	3.63	5.49	7.36
.70	8 3/8	1.82	2.76	3.71	5.61	7.52
.71	8 1/2	1.86	2.81	3.78	5.73	7.68
.72	8 5/8	1.90	2.87	3.86	5.85	7.84
.73	8 3/4	1.93	2.93	3.94	5.97	8.00
.74	8 7/8	1.97	2.99	4.02	6.09	8.17
.75	9	2.01	3.05	4.10	6.21	8.33
.76	9 1/8	2.05	3.11	4.18	6.33	8.49
.77	9 1/4	2.09	3.17	4.26	6.45	8.66
.78	9 3/8	2.13	3.23	4.34	6.58	8.82
.79	9 1/2	2.17	3.29	4.42	6.70	8.99
.80	9 5/8	2.21	3.35	4.51	6.83	9.16
.81	9 3/4	2.25	3.41	4.59	6.95	9.33
.82	9 13/16	2.29	3.47	4.67	7.08	9.50
.83	9 15/16	2.33	3.54	4.75	7.21	9.67
.84	10 1/16	2.37	3.60	4.84	7.33	9.84
.85	10 3/16	2.41	3.66	4.92	7.46	10.01
.86	10 5/16	2.46	3.72	5.01	7.59	10.19
.87	10 7/16	2.50	3.79	5.10	7.72	10.36
.88	10 9/16	2.54	3.85	5.18	7.85	10.54
.89	10 11/16	2.58	3.92	5.27	7.99	10.71
.90	10 13/16	2.62	3.98	5.35	8.12	10.89
.91	10 15/16	2.67	4.05	5.44	8.25	11.07
.92	11 1/16	2.71	4.11	5.53	8.38	11.25
.93	11 3/16	2.75	4.18	5.62	8.52	11.43
.94	11 1/4	2.79	4.24	5.71	8.65	11.61
.95	11 3/8	2.84	4.31	5.80	8.79	11.79
.96	11 1/2	2.88	4.37	5.89	8.93	11.98
.97	11 5/8	2.93	4.44	5.98	9.06	12.16
.98	11 3/4	2.97	4.51	6.07	9.20	12.34
.99	11 7/8	3.01	4.57	6.15	9.34	12.53
1.00	12	3.06	4.64	6.25	9.48	12.72
1.01	12 1/8	....	4.71	6.34	9.62	12.91
1.02	12 1/4	....	4.78	6.43	9.76	13.10
1.03	12 3/8	....	4.85	6.52	9.90	13.28
1.04	12 1/2	....	4.92	6.62	10.04	13.47
1.05	12 5/8	....	4.98	6.71	10.18	13.66
1.06	12 3/4	....	5.05	6.80	10.32	13.85
1.07	12 13/16	....	5.12	6.90	10.46	14.04
1.08	12 15/16	....	5.20	6.99	10.61	14.24
1.09	13 1/16	....	5.26	7.09	10.75	14.43
1.10	13 3/16	....	5.34	7.19	10.90	14.64
1.11	13 5/16	....	5.41	7.28	11.04	14.83
1.12	13 7/16	....	5.48	7.38	11.19	15.03
1.13	13 9/16	....	5.55	7.47	11.34	15.22
1.14	13 11/16	....	5.62	7.57	11.48	15.42
1.15	13 13/16	....	5.69	7.66	11.64	15.62
1.16	13 15/16	....	5.77	7.76	11.79	15.82
1.17	14 1/16	....	5.84	7.86	11.94	16.02
1.18	14 3/16	....	5.91	7.96	12.09	16.23
1.19	14 1/4	....	5.98	8.06	12.24	16.43

Table 1—(Concluded)

Head in Feet	Head in Inches	Discharge in cubic feet per second for crests of arious lengths: 1 foot	1.5 feet	2 feet	3 feet	4 feet
1.20	14 3/8	....	6.06	8.16	12.39	16.63
1.21	14 1/2	....	6.13	8.26	12.54	16.83
1.22	14 5/8	....	6.20	8.35	12.69	17.03
1.23	14 3/4	....	6.28	8.46	12.85	17.25
1.24	14 7/8	....	6.35	8.56	12.99	17.45
1.25	15	....	6.43	8.66	13.14	17.65
1.26	15 1/8	....	....	....	13.30	17.87
1.27	15 1/4	....	....	....	13.45	18.07
1.28	15 5/8	....	....	....	13.61	18.28
1.29	15 1/2	....	....	....	13.77	18.50
1.30	15 5/8	....	....	....	13.93	18.71
1.31	15 3/4	....	....	....	14.09	18.92
1.32	15 13/16	....	....	....	14.24	19.12
1.33	15 15/16	....	....	....	14.40	19.34
1.34	16 1/16	....	....	....	14.56	19.55
1.35	16 3/16	....	....	....	14.72	19.77
1.36	16 5/16	....	....	....	14.88	19.98
1.37	16 7/16	....	....	....	15.04	20.20
1.38	16 9/16	....	....	....	15.20	20.42
1.39	16 11/16	....	....	....	15.36	20.64
1.40	16 13/16	....	....	....	15.53	20.86
1.41	16 15/16	....	....	....	15.69	21.08
1.42	17 1/16	....	....	....	15.85	21.29
1.43	17 3/16	....	....	....	16.02	21.52
1.44	17 1/4	....	....	....	16.19	21.74
1.45	17 3/8	....	....	....	16.34	21.96
1.46	17 1/2	....	....	....	16.51	22.18
1.47	17 5/8	....	....	....	16.68	22.41
1.48	17 3/4	....	....	....	16.85	22.64
1.49	17 7/8	....	....	....	17.01	22.85
1.50	18	....	....	....	17.17	23.08

Trapezoidal or Cipolletti Weirs[5].—The trapezoidal weir, called also the Cipolletti weir after the Italian engineer who designed it, is equally accurate but more difficult to construct than the rectangular weir. As indicated in Figure 6, its sides are made on a slope of 1 inch horizontal to 4 inches vertical.

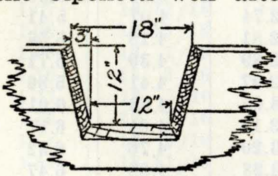

Fig. 6. Trapezoidal or Cipolletti weir

The conditions of installation above outlined apply to this weir. Discharges computed from a formula corrected on the basis of experiments above described are presented in Table 2.

[5]See footnote 1, page 8.

Table 2.—Discharge tables for Cipolletti weirs[6]

Head in Feet	Head in Inches	Discharge in cubic feet per second for crests of various lengths				
		1 foot	1.5 feet	2 feet	3 feet	4 feet
0.20	2 3/8	0.30	0.45	0.60	0.90	1.20
.21	2 1/2	.32	.48	.64	.97	1.29
.22	2 5/8	.35	.52	.69	1.04	1.38
.23	2 3/4	.37	.55	.74	1.11	1.47
.24	2 7/8	.39	.59	.79	1.18	1.57
.25	3	.42	.63	.84	1.25	1.67
.26	3 1/8	.45	.67	.89	1.33	1.77
.27	3 1/4	.47	.70	.94	1.40	1.87
.28	3 3/8	.50	.74	.99	1.48	1.97
.29	3 1/2	.53	.79	1.04	1.56	2.08
.30	3 5/8	.56	.83	1.10	1.64	2.19
.31	3 3/4	.59	.87	1.15	1.73	2.30
.32	3 13/16	.61	.91	1.21	1.80	2.41
.33	3 15/16	.64	.95	1.27	1.89	2.52
.34	4 1/16	.67	1.00	1.32	1.98	2.64
.35	4 3/16	.70	1.04	1.38	2.07	2.75
.36	4 5 16	.73	1.09	1.44	2.16	2.87
.37	4 7/16	.77	1.13	1.50	2.25	2.99
.38	4 9/16	.80	1.18	1.57	2.34	3.11
.39	4 11/16	.83	1.23	1.63	2.43	3.24
.40	4 13/16	.87	1.28	1.69	2.53	3.36
.41	4 15/16	.90	1.32	1.76	2.62	3.49
.42	5 1/16	.93	1.37	1.82	2.72	3.61
.43	5 3/16	.97	1.42	1.89	2.81	3.74
.44	5 1/4	1.00	1.47	1.95	2.91	3.87
.45	5 3/8	1.04	1.53	2.02	3.01	4.01
.46	5 1/2	1.07	1.58	2.09	3.11	4.14
.47	5 5/8	1.11	1.63	2.16	3.21	4.28
.48	5 3/4	1.15	1.68	2.23	3.32	4.41
.49	5 7/8	1.18	1.74	2.30	3.42	4.55
.50	6	1.22	1.79	1.37	3.53	4.69
.51	6 1/8	1.26	1.85	2.44	3.64	4.83
.52	6 1/4	1.30	1.90	2.51	3.74	4.97
.53	6 3/8	1.34	1.96	2.59	3.85	5.12
.54	6 1/2	1.38	2.02	2.66	3.96	5.26
.55	6 5/8	1.42	2.07	2.74	4.07	5.41
.56	6 3/4	1.46	2.13	2.81	4.18	5.56
.57	6 13/16	1.50	2.19	2.89	4.30	5.71
.58	6 15/16	1.54	2.25	2.97	4.41	5.86
.59	7 1/16	1.58	2.31	3.05	4.53	6.01
.60	7 3/16	1.62	2.37	3.13	4.64	6.17
.61	7 5/16	1.67	2.43	3.20	4.76	6.32
.62	7 7/16	1.71	2.49	3.28	4.88	6.47
.63	7 9/16	1.75	2.55	3.37	5.00	6.63
.64	7 11/16	1.80	2.62	3.45	5.12	6.79
.65	7 13/16	1.84	2.68	3.53	5.24	6.95
.66	7 15/16	1.89	2.75	3.61	5.36	7.11
.67	8 1/16	1.93	2.81	3.70	5.48	7.28
.68	8 3/16	1.98	2.87	3.79	5.61	7.44
.69	8 1/4	2.02	2.94	3.87	5.73	7.61
.70	8 3/8	2.07	3.01	3.95	5.86	7.77
.71	8 1/2	2.12	3.07	4.04	5.99	7.94
.72	8 5/8	2.16	3.14	4.13	6.12	8.11

[6]Computed from the formula $Q = 3.247\, lH^{1.48} - \frac{0.566\, l^{1.8}}{1+2\, l^{1.8}} H^{1.9} + 0.609\, H2.5$

Table 2—(Continued)

Head in Feet	Head in Inches	Discharge in cubic feet per second for crests of various lengths: 1 foot	1.5 feet	2 feet	3 feet	4 feet
.73	8 3/4	2.21	3.21	4.22	6.24	8.28
.74	8 7/8	2.26	3.28	4.31	6.38	8.45
.75	9	2.31	3.35	4.40	6.51	8.62
.76	8 1/8	2.36	3.42	4.49	6.64	8.80
.77	9 1/4	2.41	3.49	4.58	6.77	8.97
.78	9 3/8	2.46	3.56	4.67	6.90	9.15
.79	9 1/2	2.51	3.63	4.76	7.04	9.33
.80	9 5/8	2.56	3.70	4.85	7.18	9.51
.81	9 3/4	2.61	3.77	4.95	7.31	9.69
.82	9 13/16	2.66	3.84	5.04	7.45	9.87
.83	9 15/16	2.71	3.92	5.14	7.59	10.05
.84	10 1/16	2.77	3.99	5.23	7.73	10.23
.85	10 3/16	2.82	4.07	5.33	7.87	10.42
.86	10 5/16	2.87	4.14	5.43	8.01	10.60
.87	10 7/16	2.93	4.22	5.52	8.15	10.79
.88	10 9/16	2.98	4.29	5.62	8.30	10.98
.89	10 11/16	3.04	4.37	5.72	8.44	11.17
.90	10 13/16	3.09	4.45	5.82	8.59	11.36
.91	10 15/16	3.15	4.53	5.92	8.73	11.55
.92	11 1/16	3.20	4.60	6.02	8.88	11.74
.93	11 3/16	3.26	4.68	6.13	9.03	11.94
.94	11 1/4	3.32	4.76	6.23	9.17	12.13
.95	11 3/8	3.37	4.84	6.33	9.32	12.33
.96	11 1/2	3.43	4.92	6.44	9.48	12.53
.97	11 5/8	3.49	5.00	6.55	9.62	12.72
.98	11 3/6	3.55	5.09	6.64	9.78	12.92
.99	11 7/8	3.61	5.17	6.75	9.93	13.12
1.00	12	3.67	5.25	6.86	10.08	13.32
1.01	12 1/8	....	5.33	6.96	10.24	13.53
1.02	12 1/4	....	5.42	7.07	10.40	13.73
1.03	12 3/8	....	5.50	7.18	10.55	13.94
1.04	12 1/2	....	5.59	7.29	10.71	14.15
1.05	12 5/8	....	5.67	7.40	10.87	14.35
1.06	12 3/4	....	5.76	7.51	11.03	14.56
1.07	12 13/16	....	5.84	7.62	11.18	14.76
1.08	12 15/16	....	5.93	7.73	11.35	14.98
1.09	13 1/16	....	6.02	7.84	11.51	15.19
1.10	13 3/16	....	6.11	7.96	11.68	15.41
1.11	13 5/16	....	6.20	8.07	11.84	15.62
1.12	12 7/16	....	6.29	8.18	12.00	15.84
1.13	13 9/16	....	6.37	8.29	12.16	16.04
1.14	13 11/16	....	6.46	8.41	12.33	16.26
1.15	13 13/16	....	6.56	8.53	12.50	16.48
1.16	13 15/16	....	6.65	8.65	12.67	16.70
1.17	14 1/16	....	6.74	8.76	12.84	16.93
1.18	14 3/16	....	6.83	8.88	13.01	17.15
1.19	14 1/4	....	6.93	9.10	13.18	17.37
1.20	14 3/8	....	7.02	9.12	13.35	17.59
1.21	14 1/2	....	7.11	9.24	13.52	17.81
1.22	14 5/8	....	7.20	9.36	13.69	18.03
1.23	14 3/4	....	7.30	9.48	13.87	18.27
1.24	14 7/8	....	7.40	9.60	14.04	18.49
1.25	15	....	7.49	9.72	14.21	18.71
1.26	15 1/8	....	....	....	14.39	18.95
1.27	15 1/4	....	....	....	14.56	19.17

Table 2—(Concluded)

Head in Feet	Head in Inches	Discharge in cubic feet per second for crests of various lengths: 1 foot	1.5 feet	2 feet	3 feet	4 feet
1.28	15 3/8	....	....	....	14.74	19.41
1.29	15 1/2	....	....	....	14.92	19.65
1.30	15 5/8	....	....	....	15.11	19.88
1.31	15 3/4	....	....	....	15.29	20.12
1.32	15 13/16	....	....	....	15.46	20.34
1.33	15 15/16	....	....	....	15.64	20.58
1.34	16 1/16	....	....	....	15.82	20.82
1.35	16 3/16	....	....	....	16.01	21.06
1.36	16 5/16	....	....	....	16.19	21.29
1.37	16 7/16	....	....	....	16.37	21.53
1.38	16 9/16	....	....	....	16.57	21.78
1.39	16 11/16	....	....	....	16.75	22.02
1.40	16 13/16	....	....	....	16.94	22.27
1.41	16 15/16	....	....	....	17.13	22.51
1.42	17 1/16	....	....	....	17.31	22.75
1.43	17 3/16	....	....	....	17.51	23.01
1.44	17 1/4	....	....	....	17.70	23.26
1.45	17 3/8	....	....	....	17.89	23.50
1.46	17 1/2	....	....	....	18.08	23.75
1.47	17 5/8	....	....	....	18.28	24.01
1.48	17 3/4	....	....	....	18.47	24.26
1.49	17 7/8	....	....	....	18.66	24.50
1.50	18	....	....	....	18.85	24.75

Ninety-Degree (90°) Triangular-Notch Weirs[7].—The triangular-notch weir is especially adapted to the measurement of small quantities of water, varying from a very small fraction of a second-foot to 2 or 3 second-feet.

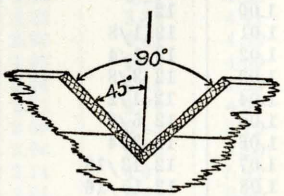

Fig. 7. Triangular notch weir

Cone has demonstrated that very small crest lengths in the rectangular and trapezoidal weir, e. g., 1/2 foot, do not follow the laws of discharge for lengths of 1 foot and above. Therefore, for the measurement of streams of 1/3 of 1 c.f.s. or less, which are too small for the 1-foot rectangular weir, the triangular-notch weir is especially valuable. The 90-degree weir should be so placed that each side will make an angle of 45 degrees or half pitch with the vertical.

Discharges for the triangular weir under depths varying from 2 to 15 inches are presented in Table 3, which shows, for example, that if the depth of water over the vertex, or lowest point in the notch, is 9 inches the discharge would be 1.22 second feet.

[7]See footnote 1, page 8.

Table 3.—Discharge table for 90° triangular notch[8]

Head in Feet	Head in Inches	Discharge in Second-feet (Q.)	Head in Feet	Head in Inches	Discharge in Second-feet (Q.)	Head in Feet	Head in Inches	Discharge in Second-feet (Q.)
0.20	2 3/8	0.046	0.55	6 5/8	0.564	0.90	10 13/16	1.92
.21	2 1/2	.052	.56	6 3/4	.590	.91	10 15/16	1.97
.22	2 5/8	.058	.57	6 13/16	.617	.92	11 1/16	2.02
.23	2 3/4	.065	.58	6 15/16	.644	.93	11 3/16	2.08
.24	2 7/8	.072	.59	1 1/16	.672	.94	11 1/4	2.13
.25	3	.080	.60	7 3/16	.700	.95	11 3/8	2.19
.26	3 1/8	.088	.61	7 5/16	.730	.96	11 1/2	2.25
.27	3 1/4	.096	.62	7 7/16	.760	.97	11 5/8	2.31
.28	3 3/8	.106	.63	7 9/16	.790	.98	11 3/4	2.37
.29	3 1/2	.115	.64	7 11/16	.822	.99	11 7/8	2.43
.30	3 5/8	.125	.65	7 13/16	.854	1.00	12	2.49
.31	3 3/4	.136	.66	7 15/16	.887	1.01	12 1/8	2.55
.32	3 13/16	.147	.67	8 1/16	.921	1.02	12 1/4	2.61
.33	3 15/16	.159	.68	8 3/16	.955	1.03	12 3/8	2.68
.34	4 1/16	.171	.69	8 1/4	.991	1.04	12 1/2	2.74
.35	4 3/16	.184	.70	8 3/8	1.03	1.05	12 5/8	2.81
.36	4 5/16	.197	.71	8 1/2	1.06	1.06	12 3/4	2.87
.37	4 7/16	.211	.72	8 5/8	1.10	1.07	12 13/16	2.94
.38	4 9/16	.226	.73	8 3/4	1.14	1.08	12 15/16	3.01
.39	4 11/16	.240	.74	8 7/8	1.18	1.09	13 1/16	3.08
.40	4 13/16	.256	.75	9	1.22	1.10	13 3/16	3.15
.41	4 15/16	.272	.76	9 1/8	1.26	1.11	13 5/16	3.22
.42	5 1/16	.289	.77	9 1/4	1.30	1.12	13 7/16	3.30
.43	5 3/16	.306	.78	9 3/8	1.34	1.13	13 9/16	3.37
.44	5 1/4	.324	.79	9 1/2	1.39	1.14	13 11/16	3.44
.45	5 3/8	.343	.80	9 5/8	1.43	1.15	13 13/16	3.52
.46	5 1/2	.362	.81	9 3/4	1.48	1.16	13 15/16	3.59
.47	5 5/8	.382	.82	9 13/16	1.52	1.17	14 1/16	3.67
.48	5 3/4	.403	.83	9 15/16	1.57	1.18	14 3/16	3.75
.49	5 7/8	.424	.84	10 1/16	1.61	1.19	14 1/4	3.83
.50	6	.445	.85	10 3/16	1.66	1.20	14 3/8	3.91
.51	6 1/8	.468	.86	10 5/16	1.71	1.21	14 1/2	3.99
.52	6 1/4	.491	.87	10 7/16	1.76	1.22	14 5/8	4.07
.53	6 3/8	.515	.88	10 9/16	1.81	1.23	14 3/4	4.16
.54	6 1/2	.539	.89	10 11/16	1.86	1.24	14 7/8	4.24
						1.25	15	4.33

[8]Computed from the formula $Q = 2.49\ H^{2.48}$

Suppressed Weirs[9].—A standard rectangular weir without end contractions, commonly called the suppressed weir, consists of a wall having a sharp crest built across a rectangular channel, high enough to cause a complete deflection of water filaments as the stream passes over the weir. The conditions for accuracy are the same as for the standard rectangular weir with contractions, except for those relating to side contractions. This type of weir can be used only in channels having a uniform rectangular cross-section.

[9]See footnote 1, page 8.

Air holes must be made through the weir box just below the weir crest so as fully to admit air under the sheet of over-falling water.

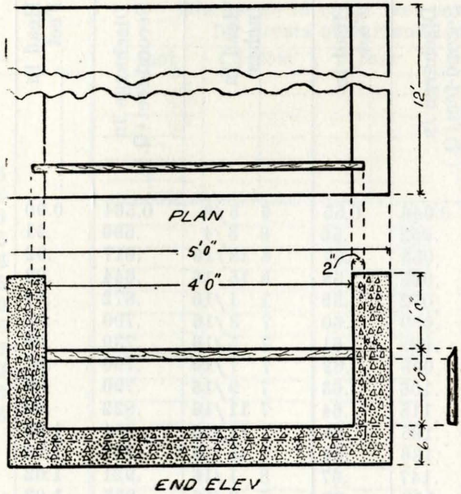

Fig. 8. Suppressed weir

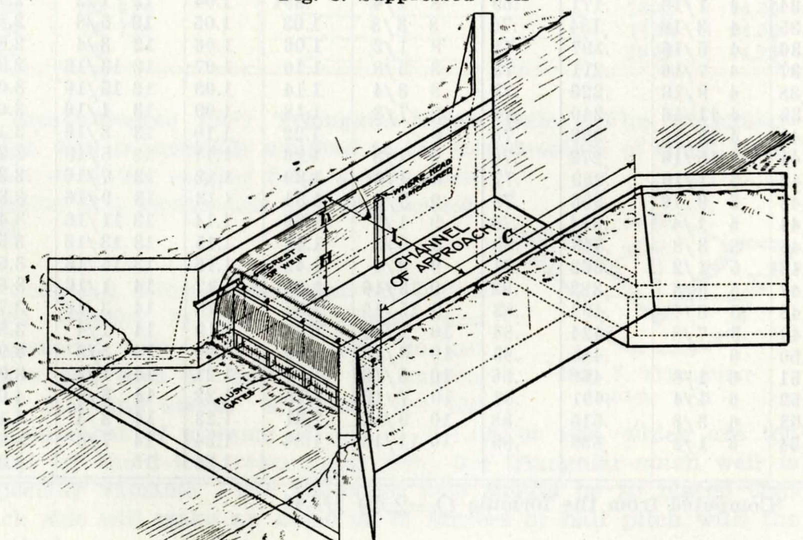

Fig. 9. Lyman rectangular weir without end contractions

Approximate discharges over the standard weir without end contractions may be obtained by the use of Table 2. More accurate measurements may be made with this type of weir by using Table 4 which has been prepared from a more extensive table based on experimental work done by Dr. Richard R. Lyman[10].

[10]Lyman, Richard R. "Measurement of Flowing Streams." Utah Engin. Exp. Sta. Bul. 5: p. 4, (1912). (University of Utah)

Table 4.—Discharge tables for one foot of length of Lyman's rectangular weir

Head in Inches	Head in Feet	Weir 0.5 ft. high	Weir 0.75 ft. high	Weir 1 ft. high	Weir 1.5 ft. high	Weir 2 ft. high	Weir 3 ft. high
2 3/8	0.20	0.32	0.31	0.31	0.31	0.31	0.31
2 1/2	0.21	0.34	0.34	0.34	0.34	0.33	0.33
2 5/8	0.22	0.37	0.36	0.36	0.36	0.36	0.36
2 3/4	0.23	0.39	0.39	0.39	0.38	0.38	0.38
2 7/8	0.24	0.42	0.42	0.41	0.41	0.41	0.41
3	0.25	0.45	0.44	0.44	0.44	0.43	0.43
3 1/8	0.26	0.48	0.47	0.47	0.48	0.46	0.46
3 1/4	0.27	0.50	0.50	0.40	0.49	0.49	0.48
3 3/8	0.28	0.53	0.52	0.52	0.51	0.51	0.51
3 1/2	0.29	0.56	0.55	0.55	0.54	0.54	0.54
3 5/8	0.30	0.60	0.58	0.58	0.57	0.57	0.56
3 11/16	0.31	0.63	0.61	0.61	0.60	0.60	0.59
3 13/16	0.32	0.66	0.65	0.64	0.63	0.63	0.62
3 15/16	0.33	0.69	0.67	0.67	0.66	0.65	0.65
4 1/16	0.34	0.72	0.71	0.70	0.69	0.68	0.68
4 3/16	0.35	0.76	0.74	0.73	0.72	0.71	0.71
4 5/16	0.36	0.79	0.77	0.76	0.75	0.75	0.74
4 7/16	0.37	0.82	0.80	0.79	0.78	0.78	0.77
4 9/16	0.38	0.86	0.84	0.83	0.81	0.81	0.80
4 11/16	0.39	0.90	0.87	0.86	0.85	0.84	0.83
4 13/16	0.40	0.93	0.91	0.89	0.88	0.87	0.86
4 15/16	0.41	0.97	0.94	0.93	0.91	0.90	0.90
5 1/16	0.42	1.01	0.98	0.96	0.94	0.94	0.92
5 1/8	0.43	1.05	1.01	1.00	0.98	0.97	0.96
5 1/4	0.44	1.08	1.05	1.03	1.01	1.00	0.99
5 3/8	0.45	1.12	1.08	1.06	1.04	1.03	1.02
5 1/2	0.46	1.16	1.13	1.11	1.09	1.07	1.06
5 5/8	0.47	1.21	1.16	1.14	1.12	1.11	1.10
5 3/4	0.48	1.25	1.21	1.19	1.16	1.15	1.13
5 7/8	0.49	1.29	1.25	1.22	1.20	1.18	1.17
6	0.50	1.34	1.29	1.26	1.24	1.22	1.20
6 1/8	0.51	1.37	1.32	1.30	1.27	1.26	1.24
6 1/4	0.52	1.42	1.36	1.34	1.31	1.29	1.27
6 3/8	0.53	1.47	1.41	1.38	1.35	1.33	1.31
6 1/2	0.54	1.51	1.44	1.42	1.39	1.37	1.35
6 9/16	0.55	1.56	1.49	1.46	1.43	1.41	1.39
6 11/16	0.56	1.60	1.53	1.50	1.46	1.44	1.42
6 13/16	$.57	1.64	1.57	1.54	1.50	1.48	1.46
6 15/16	0.58	1.69	1.61	1.58	1.54	1.52	1.50
7 1/16	0.59	1.74	1.67	1.63	1.59	1.57	1.55
7 3/16	0.60	1.79	1.70	1.68	1.63	1.61	1.58
7 5/16	0.61	1.83	1.75	1.72	1.68	1.65	1.63
7 7/16	0.62	1.88	1.80	1.76	1.71	1.69	1.67
7 9/16	0.63	1.93	1.85	1.81	1.76	1.73	1.71
7 11/16	0.64	1.98	1.90	1.86	1.82	1.79	1.76
7 13/16	0.65	2.04	1.93	1.89	1.84	1.81	1.78
7 15/16	0.66	2.09	1.99	1.95	1.89	1.87	1.83
8 1/16	0.67	2.14	2.03	1.98	1.93	1.90	1.87
8 1/8	0.68	2.19	2.08	2.03	1.98	1.95	1.91
8 1/4	0.69	2.24	2.13	2.08	2.03	1.99	1.96
8 3/8	0.70	2.30	2.18	2.13	2.07	2.03	2.00
8 1/2	0.71	2.35	2.22	2.17	2.12	2.09	2.04
8 5/8	0.72	2.41	2.28	2.22	2.16	2.13	2.09
8 3/4	0.73	2.47	2.33	2.27	2.20	2.18	2.14

Table 4—(Continued)

Head in Inches	Head in Feet	Weir 0.5 ft. high	Weir 0.75 ft. high	Weir 1 ft. high	Weir 1.5 ft. high	Weir 2 ft. high	Weir 3 ft. high
8 7/8	0.74	2.52	2.38	2.32	2.25	2.21	2.17
9	0.75	2.59	2.43	2.38	2.30	2.26	2.23
9 1/8	0.76	2.64	2.48	2.42	2.34	2.30	2.27
9 1/4	0.77	2.70	2.54	2.47	2.40	2.35	2.30
9 3/8	0.78	2.76	2.59	2.52	2.44	2.40	2.35
9 1/2	0.79	2.82	2.63	2.57	2.48	2.43	2.38
9 9/16	0.80	2.89	2.70	2.63	2.55	2.50	2.44
9 11/16	0.81	2.94	2.76	2.68	2.60	2.55	2.49
9 13/16	0.82	3.01	2.81	2.74	2.64	2.59	2.53
9 15/16	0.83	3.07	2.87	2.79	2.70	2.64	2.58
10 1/16	0.84	3.13	2.93	2.84	2.76	2.70	2.63
10 3/16	0.85	3.19	2.99	2.91	2.80	2.75	2.68
10 5/16	0.86	3.26	3.04	2.96	2.86	2.80	2.74
10 7/16	0.87	3.32	3.10	3.01	2.91	2.84	2.78
10 9/16	0.88	3.40	3.16	3.07	2.97	2.90	2.82
10 11/16	0.89	3.45	3.20	3.12	3.01	2.94	2.86
10 13/16	0.90	3.52	3.27	3.18	3.07	3.00	2.92
10 15/16	0.91	3.58	3.33	3.24	3.12	3.06	2.97
11 1/16	0.92	3.66	3.39	3.29	3.18	3.11	3.03
11 1/8	0.93	3.72	3.45	3.35	3.23	3.16	3.08
11 1/4	0.94	3.80	3.51	3.41	3.29	3.21	3.13
11 3/8	0.95	3.87	3.58	3.47	3.35	3.26	3.18
11 1/2	0.96	3.94	2.64	3.54	3.40	3.33	3.24
11 5/8	0.97	4.01	3.70	3.59	3.45	3.37	3.28
11 3/4	0.98	4.08	3.77	3.65	3.52	3.43	3.33
11 7/8	0.99	4.15	3.83	3.71	3.58	3.48	3.38
12	1.00	4.23	3.90	3.78	3.64	3.56	3.44

It will be noted that the discharges in Table 4 are given for one-foot length of weir. The total discharge is, therefore, obtained by multiplying the discharge as read by the length of the weir in feet. For example, the discharge over a weir one foot high under a head of 6 inches is 1.26 second feet. If, therefore, the weir crest is 4 feet long the total discharge would be 4x1.26, or 5.04 second-feet.

Table 5 contains suggestive dimensions of weirs without end contractions to be used for the measurement of various amounts of water. In order easily to understand the contents of Table 5, reference should be made to Figure 9[11], in which the meanings of the letters "H", "h", "L" and "C" are indicated.

[11]See footnote 10, page 16.

Table 5.—Suggestive dimensions of weirs to be used for measuring various quantities of flowing water

Smallest Quantity to be Measured (c.f.s.)	Largest Quantity to be Measured (c.f.s.)	h Distance from Crest to top of Wall (ft.)	L Length of Crest and Width of Channel (ft.)	H Height of Weir (ft.)	C Length of Channel (ft.)
0.05	0.25	0.5	0.2	0.50	2
0.15	0.60	0.5	0.5	0.50	4
0.30	1.30	0.5	1.0	0.50	6
0.45	1.90	0.5	1.5	0.75	8
0.60	3.2	0.5	2.0	0.75	10
0.75	3.2	0.5	2.5	0.75	10
1.0	3.7	0.5	3.0	1.0	10
1.5	11.0	1.0	3.5	1.0	12
2.0	15.0	1.0	4.0	1.0	12
2.5	18.0	1.0	5.0	1.5	12
3.0	21.0	1.0	6.0	1.5	14
3.5	25.0	1.0	7.0	1.5	14
4.0	28.0	1.0	8.0	2.0	14
4.5	32.0	1.0	9.0	2.0	16
5.0	65	1.5	10.0	2.0	16
6.0	71	1.5	11.0	2.0	16
7.0	78	1.5	12.0	2.0	16
8.0	84	1.5	13.0	2.0	16
9.0	91	1.5	14.0	3.0	18
10.0	97	1.5	15.0	3.0	18
11.0	104	1.5	16.0	3.0	18
11.0	104	1.5	16.0	3.0	18
12.0	170	2.0	17.0	3.0	18
13.0	180	3.0	18.0	3.0	18
14.0	200	2.0	20.0	3.0	20

Weir Construction.—The type of soil will largely determine whether a simple weir bulkhead and weir pond may be used or whether a weir box should be built. In the heavy clay soils where little washing occurs a simple bulkhead can be used to an advantage, but in light soils, subject to erosion, a weir box should be used, with wing walls and cutoff walls to prevent the washing out of the structure.

Figure 3 is an isometric drawing of a simple weir bulkhead which can easily be constructed on the farm. With this type of weir the head is usually measured from a stake in the weir pond set level with the crest.

Figure 10[12] is an isometric drawing of a weir box. The letters, together with Table 6, give the sizes of weirs best adapted to measuring streams of water varying from 0.5 to 22 cubic feet per second.

[12]See footnote 2, page 8.

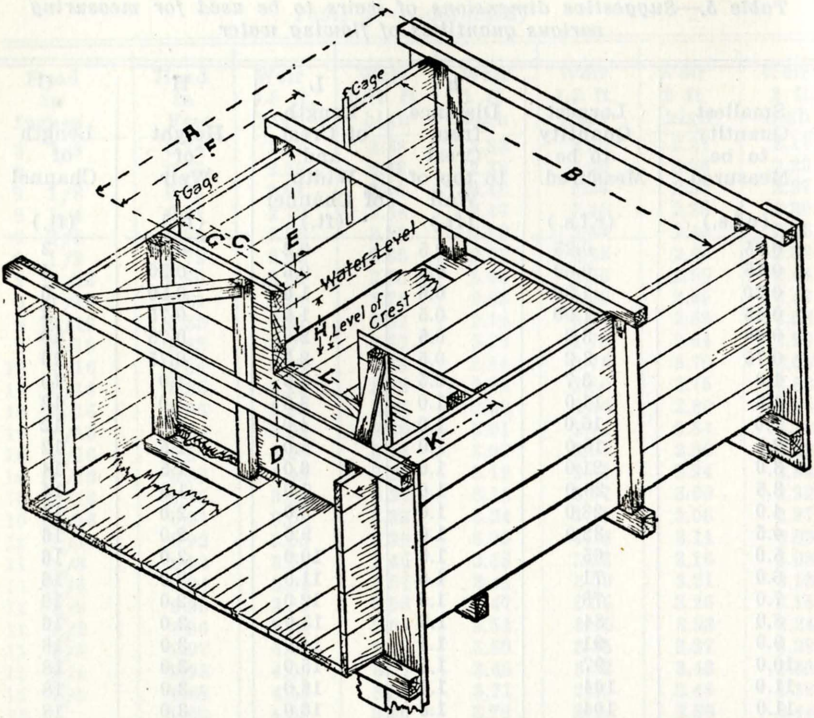

Fig. 10. Plan of weir box

The weir dimensions in Table 6 illustrated in Figure 10, as given by Cone[13], are a little smaller than what would be necessary to obtain rigid accuracy, but boxes of these sizes will give results within 1 per cent of the correct values.

Don'ts in Regard to Weirs.—For further emphasis on proper use of weirs, the following "don'ts" are included:

1. Don't set weir immediately below a curve in the ditch, as the curve will cause the water to flow to the side of the crest.
2. Don't set it immediately below or too close to a headgate where the water has high velocity, as it will cause too high a velocity of approach.
3. Don't allow the water below the weir to back up even with the crest as it will not allow complete contraction and will cut down the discharge.
4. Don't set the weir any other way than perpendicular and at right angles to the flow of the stream.
5. Don't attempt to use too small a weir. Put in a larger weir where the water to be measured exceeds a depth on the crest of one-third the crest length.
6. Don't allow the pool above the weir to fill up with sediment, as the resulting decrease in the cross-section will increase the velocity of approach.

[13]See footnote 2, page 8.

Table 6.—Weir-box dimensions for rectangular, Cipolletti, and 90-degree triangular-notch weirs

(All dimensions are in feet. The letters at the heads of the columns in this table refer to Figure 10.)

Flow (second feet)	H Maximum head	L Length of weir crest	A Length of box above weir notch	K Length of box below weir notch	B Total width of box	E* Total depth of box	C End of Crest to side	D Crest to bottom	F† Hook gage distance	G§ Hook gage distance
Rectangular and trapezoidal weirs with end contractions										
½ to 3	1.0	1	6	2	5½	3½	2¼	2	4	2
2 to 5	1.1	1½	7	3	7	4	2¾	2½	4½	2
4 to 8	1.2	2	8	4	8½	4½	3¼	2¾	5	2½
6 to 14	1.3	3	9	5	12	5	4½	3¼	5½	3
10 to 22	1.5	4	10	6	14	5½	5	3½	6	3
90-degree triangular notch weir										
½ to 2½	1.00	....	6	2	5	3	2½	1½	4	2
2 to 4 1/3	1.25	....	6½	8½	6½	3¼	3¼	1½	5	2½

Making a Discharge Measurement with a Weir.—Assuming that the weir is properly installed and that the flow through the notch has become steady, to make a measurement the depth of water over the crest of the weir is determined by placing a carpenter's rule on the stake or lug which has been fixed level with the crest, or by reading the weir scale. With the head determined enter the table of discharges for the weir being used. The tables are constructed so that the head may be measured either in feet or inches and also for crest lengths of from 1 to 4 feet. For example, suppose that the head on the crest measured 6.5 inches, over a 2-foot crest, a rectangular weir being used. Enter the column marked "Head in inches" and follow downward to 6.5. Move to the right until you intersect the column under discharge in cubic feet per second marked "2 feet". This figure at this intersection (2.53) is the discharge in cubic feet per second (c.f.s.).

*This distance allows for about ½ foot freeboard above highest water level in weir box.

†Equals distance from crest upstream to gage.

§Equals distance from end of crest over to gage.

SUBMERGED ORIFICES

For sections in which the grade of the ditch is so flat that it is difficult to get the required head for flow over a weir and where the waters carry heavy loads of silt, a device called a submerged orifice is used.

An orifice is a hole or opening cut in a bulkhead through which the water flows. If the opening is below the water surface on both sides of the bulkhead, it is said to be submerged. If the water surface on the downstream side is below the opening it is said to have a free discharge. Only the submerged orifice is considered here.

Submerged orifices may be divided into two types: (1) Those with orifices of fixed dimensions and (2) those built so that the height of opening may be varied. A standard submerged orifice is one in which the opening is rectangular and the sides of which are sharp-edged. The adjustable submerged orifice is one in which the height of opening and head may be varied to fit the conditions. It is usually built with suppressed side and end contractions. The ordinary form is the simple headgate. Of these two types the standard submerged orifice is the more accurate. Figures 11 and 12 show the standard end adjustable types, respectively.

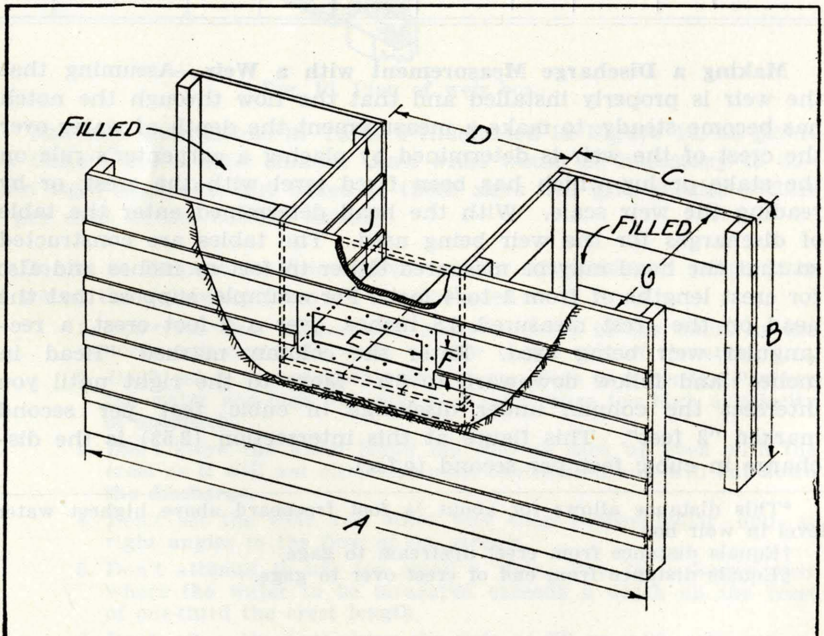

Fig. 11. Isometric drawing of standard submerged orifice

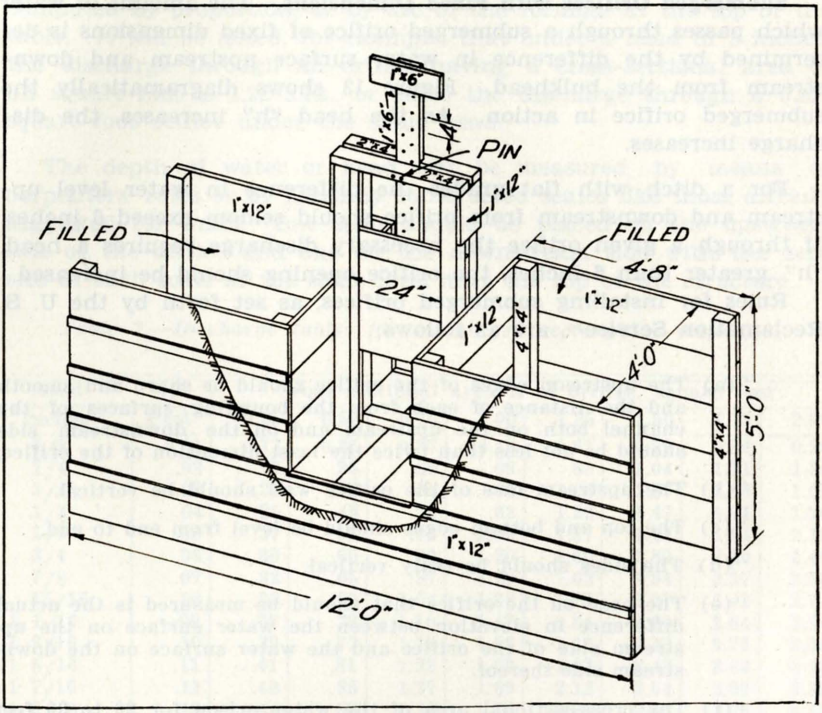

Fig. 12. Isometric drawing of adjustable submerged orifice

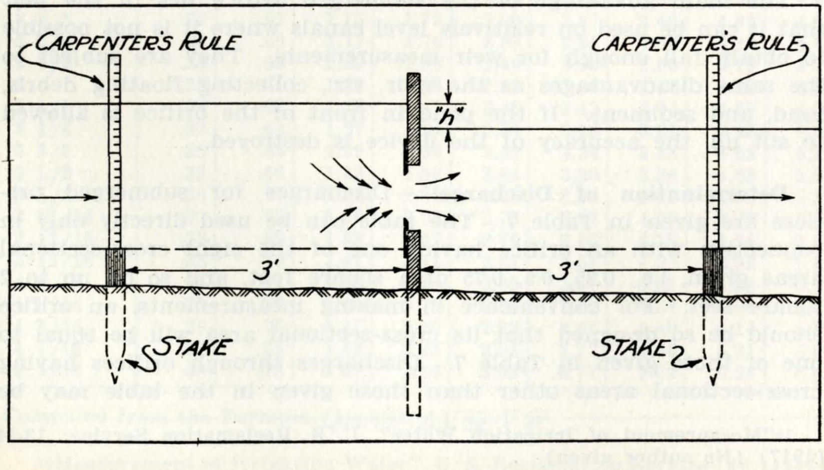

Fig. 13. Diagramatic sketch showing the submerged orifice in operation

Submerged Orifices with Fixed Dimensions.—The amount of water which passes through a submerged orifice of fixed dimensions is determined by the difference in water surface upstream and downstream from the bulkhead. Figure 13 shows diagramatically the submerged orifice in action. As the head "h" increases, the discharge increases.

For a ditch with flat grades the difference in water level upstream and downstream from orifice should seldom exceed 6 inches. If through a given orifice the necessary discharge requires a head, "h", greater than 6 inches, the orifice opening should be increased.

Rules for installing submerged orifices, as set forth by the U. S. Reclamation Service[14], are as follows:

"(a) The upstream edges of the orifice should be sharp and smooth and the distance of each from the bounding surfaces of the channel both on the upstream and on the downstream side should be not less than twice the least dimension of the orifice.

"(b) The upstream face of the orifice wall should be vertical.

"(c) The top and bottom edges should be level from end to end.

"(d) The sides should be truly vertical.

"(e) The head on the orifice that should be measured is the actual difference in elevation between the water surface on the upstream side of the orifice and the water surface on the downstream side thereof.

"(f) The cross-sectional area of the water prison for 20 to 30 feet from the orifice, on the upstream and on the downstream side thereof, should be at least six times the cross sectional area of the orifice.

"(g) Correction should be made for velocity of approach where appreciable errors are caused by neglecting the head due to it."

The main advantage of the submerged orifice lies in the fact that it can be used on relatively level canals where it is not possible to obtain fall enough for weir measurements. They are subject to the same disadvantages as the weir, viz., collecting floating debris, sand, and sediment. If the pond in front of the orifice is allowed to silt up, the accuracy of the device is destroyed.

Determination of Discharge[15].—Discharges for submerged orifices are given in Table 7. The table can be used directly only in connection with an orifice having one of the eight cross-sectional areas given, i.e., 0.25, 0.5, 0.75 of a square foot, and so on up to 2 square feet. For convenience in making measurements, an orifice should be so designed that its cross-sectional area will be equal to one of those given in Table 7. Discharges through orifices having cross-sectional areas other than those given in the table may be

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[14]"Measurement of Irrigation Water". U. S. Reclamation Service: 13-14 (1917) (No author given)

[15]See footnote 1, page 8.

computed by proportion, or by use of the formula at the top of the table. It will be noted, for example, that under a head of 3 inches, the discharge through an orifice having a cross-sectional area of 0.5 square-foot is 1.22 c.f.s., or twice the discharge through a 0.25-square-foot orifice under the same head.

The depth of water or head may be measured by means of carpenters' rules or by specially constructed scales like those already suggested for weirs. One scale should be placed on the upstream side of the orifice and one on the downstream side with the zero end of each scale at the same level near the top of the structure.

Table 7.—Discharge tables for submerged rectangular orifices[16]

Head	"H"	Cross sectional area A of orifice, square feet							
Inches	Feet	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
1/8	0.01	0.12	0.25	0.37	0.49	0.61	0.73	0.86	0.98
1/4	.02	.17	.35	.52	.69	.68	1.04	1.21	1.38
3/8	.03	.21	.42	.64	.85	1.06	1.27	1.48	1.69
1/2	.04	.25	.49	.73	.98	1.22	1.47	1.71	1.96
5/8	.50	.27	.55	.82	1.09	1.37	1.64	1.91	2.19
3/4	.06	.30	.60	.90	1.20	1.50	1.80	2.10	2.40
7/8	.07	.32	.65	.97	1.29	1.62	1.94	2.27	2.59
15/16	.08	.35	.69	1.04	1.38	1.73	2.07	2.42	2.77
1 1/16	.09	.37	.73	1.10	1.47	1.84	2.20	2.64	2.94
1 3/16	.10	.39	.77	1.16	1.56	1.93	2.32	2.71	3.09
1 5/16	.11	.41	.81	1.22	1.62	2.03	2.43	2.84	3.24
1 7/16	.12	.42	.85	1.27	1.69	2.12	2.54	2.97	3.39
1 9/16	.13	.44	.88	1.32	1.76	2.21	2.65	3.09	3.53
1 11/16	.14	.46	.92	1.37	1.83	2.29	2.75	3.20	3.66
1 13/16	.15	.47	.95	1.42	1.90	2.37	2.84	3.32	3.79
1 15/16	.16	.49	.98	1.47	1.96	2.45	2.93	3.42	3.91
2 1/16	.17	.50	1.01	1.51	2.02	2.52	3.02	3.53	4.03
2 3/16	.18	.52	1.04	1.56	2.08	2.59	3.11	3.63	4.15
2 1/4	.19	.53	1.07	1.60	2.13	2.67	3.20	3.73	4.26
2 3/8	.20	.55	1.09	1.64	2.19	2.74	3.28	3.83	4.36
2 1/2	.21	.56	1.12	1.68	2.24	2.80	3.36	3.92	4.48
2 5/8	.22	.57	1.15	1.72	2.30	2.87	3.46	4.02	4.59
2 3/4	.23	.59	1.17	1.76	2.35	2.93	3.52	4.10	4.69
2 7/8	.24	.60	1.20	1.80	2.40	3.00	3.60	4.19	4.79
3	.25	.61	1.22	1.83	2.45	3.06	3.67	4.28	4.89
3 1/8	.26	.62	1.25	1.87	2.49	3.12	3.74	4.37	4.99
3 1/4	.27	.64	1.27	1.91	2.54	3.18	3.81	4.45	5.08
3 3/8	.28	.65	1.29	1.94	2.59	3.24	3.88	4.53	5.18
3 1/2	.29	.66	1.32	1.98	2.64	3.30	3.96	4.62	5.28
3 5/8	.30	.67	1.34	2.01	2.68	3.35	4.02	4.69	5.36
3 11/16	.31	.68	1.36	2.05	2.73	3.41	4.09	4.77	5.45
3 13/16	.32	.69	1.38	2.07	2.76	3.46	4.15	4.84	5.53
3 15/16	.33	.70	1.41	2.11	2.81	3.51	4.22	4.92	5.62
4 1/16	.34	.71	1.43	2.14	2.85	3.57	4.28	4.99	5.70
4 3/16	.35	.72	1.45	2.17	2.89	3.62	4.34	5.06	5.78
4 5/16	.36	.73	1.47	2.20	2.93	3.67	4.40	5.14	5.87
4 7/16	.37	.75	1.49	2.23	2.98	3.72	4.46	5.21	5.95
4 9/16	.38	.75	1.51	2.26	3.02	3.77	4.52	5.28	6.03

Computed from the Formula $Q = 0.61\, A\sqrt{2g}\,\sqrt{H}$

[16]Measurement of Irrigation Water". U. S. Reclamation Service: 48 (1917). (With slight modifications).

Table 7—(Continued)

Head	"H"	Cross sectional area A of orifice, square feet							
Inches	Feet	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
4 11/16	.39	.76	1.53	2.29	3.05	3.82	4.58	5.35	6.11
4 13/16	.40	.77	1.55	2.32	3.09	3.87	4.64	5.42	6.19
4 15/16	.41	.78	1.57	2.35	3.12	3.92	4.70	5.48	6.27
5 1/16	.42	.79	1.59	2.38	3.17	3.96	4.75	5.55	6.34
5 1/8	.43	.80	1.60	2.41	3.21	4.01	4.81	5.61	6.42
5 1/4	.44	.81	1.62	2.43	3.24	4.06	4.87	5.68	6.49
5 3/8	.45	.82	1.64	2.46	3.28	4.10	4.92	5.74	6.56
5 1/2	.46	.83	1.66	2.49	3.32	4.15	4.98	5.81	6.64
5 5/8	.47	.84	1.68	2.52	3.36	4.20	5.04	5.87	6.71
5 3/4	.48	.85	1.70	2.54	3.39	4.24	5.08	5.93	6.78
5 7/8	.49	.86	1.71	2.57	3.42	4.28	5.14	5.99	6.85
6	.50	.87	1.73	2.59	3.46	4.32	5.19	6.05	6.92
6 1/8	.51	.87	1.75	2.62	3.49	4.37	5.24	6.11	6.99
6 1/4	.52	.88	1.76	2.65	3.53	4.41	5.29	6.17	7.05
6 3/8	.53	.89	1.78	2.67	3.56	4.45	5.34	6.23	7.12
6 1/2	.54	.90	1.80	2.70	3.59	4.49	5.39	6.29	7.19
6 9/16	.55	.91	1.81	2.72	3.63	4.53	5.44	6.35	7.25
6 11/16	.56	.92	1.83	2.75	3.66	4.58	5.49	6.41	7.32
6 13/16	.57	.92	1.85	2.77	3.69	4.62	5.54	6.46	7.38
6 15/16	.58	.93	1.86	2.79	3.73	4.66	5.59	6.52	7.45
7 1/16	.59	.94	1.88	2.82	3.76	4.70	5.64	6.58	7.51
7 3/16	.60	.95	1.90	2.84	3.79	4.74	5.68	6.63	7.58
7 5/16	.61	.96	1.91	2.87	3.82	4.78	5.73	6.69	7.64
7 7/16	.62	.96	1.93	2.89	3.85	4.81	5.76	6.74	7.70
7 9/16	.63	.97	1.94	2.91	3.88	4.85	5.82	6.79	7.76
7 11/16	.64	.98	1.96	2.93	3.91	4.89	5.87	6.85	7.82
7 13/16	.65	.99	1.97	2.96	3.94	4.93	5.92	6.90	7.89
7 15/16	.66	.99	1.99	2.98	3.97	4.97	5.96	6.95	7.95
8 1/16	.67	1.00	2.00	3.00	4.00	5.01	6.01	7.01	8.01
8 1/8	.68	1.01	2.02	3.02	4.03	5.04	6.05	7.06	8.06
8 1/4	.69	1.02	2.03	3.05	4.06	5.08	6.10	7.11	8.13
8 3/8	.70	1.02	2.05	3.07	4.09	5.12	6.14	7.16	8.18
8 1/2	.71	1.03	2.06	3.09	4.12	5.16	6.19	7.22	8.25
8 5/8	.72	1.04	2.08	3.11	4.15	5.19	6.23	7.27	8.30
8 3/4	.73	1.05	2.09	3.14	4.18	5.23	6.27	7.32	8.36
8 7/8	.74	1.05	2.10	3.16	4.21	5.26	6.31	7.37	8.42
9	.75	1.06	2.12	3.18	4.24	5.30	6.36	7.41	8.48
9 1/8	.76	1.07	2.13	3.20	4.26	5.33	6.40	7.46	8.53
9 1/4	.77	1.07	2.15	3.22	4.29	5.36	6.43	7.51	8.58
9 3/8	.78	1.08	2.16	3.24	4.32	5.40	6.48	7.56	8.64
9 1/2	.79	1.09	2.17	3.26	4.35	5.44	6.52	7.61	8.70
9 1/16	.80	1.09	2.19	3.28	4.38	5.47	6.56	7.66	8.75

Table 8 contains dimensions and lumber for standard sizes of submerged rectangular orifices adopted by the U. S. Reclamation Service and brought together in Bulletin 274[17] of the Agricultural Experiment Station, University of California. Table 8 should be read in connection with Figure 11, a drawing of the Reclamation Service orifice.

[17]Adams, Frank, Beckett, S. H., et al. "Some Measuring Devices Used in the Delivery of Irrigation Water". Calif. Agr. Exp. Sta. Bul. 247:147 (1915)

Table 8.—Dimensions and lumber for standard sizes of submerged rectangular orifices adopted by U. S. Reclamation Service

Size of Orifice			Head-wall	Side	Struc-	Floor	Approximate
Height (ft.) F	Length (ft.) E	Area (Sq.ft.) FxE	height (ft.) B	height (ft.) J	ture (ft.) C	width (ft.) D	quantity of lumber (ft.B.M.)
	1.00	0.25	3.0	2.5	4.0	2.0	150
0.25	2.00	0.50	3.0	2.5	4.0	3.0	170
	3.00	0.75	3.0	2.5	4.0	4.0	185
	1.00	0.50	3.0	2.5	4.0	2.0	150
	1.50	0.75	3.0	2.0	4.0	2.5	160
0.50	2.00	1.00	3.0	2.5	4.0	3.0	170
	2.50	1.25	3.0	2.5	4.0	3.5	175
	3.00	1.50	3.5	2.5	4.0	4.0	210
	1.33	1.00	3.0	2.5	4.0	2.0	150
	1.67	1.25	3.0	2.5	4.0	2.5	160
0.75	2.00	1.50	3.0	2.5	4.0	3.0	170
	2.33	1.75	3.5	3.0	4.0	3.0	190
	2.67	2.00	3.5	3.0	4.0	3.5	200

If no tables of discharge are available, this device can still be used by the irrigator because the discharge can be determined by the following simple relationship:

Let Q = discharge in cubic feet per second (c.f.s.)
A = area of opening in square feet
V = velocity through opening in feet per second
C = coefficient which is equal to 0.61 for a standard orifice
H = difference in head in feet

Since

$Q = AV$
$V = 8.02 \times 0.61 \times H^{\frac{1}{2}}$
$H^{\frac{1}{2}}$ equals that number which multiplied by itself equals H.

Therefore,

$Q = 8.02 \times 0.61\ A(H)^{\frac{1}{2}}$

Example

Area of opening = 2 square feet
Measured difference in head = 0.5 foot
Discharge = 8.02x2x0.61x0.707 = 6.91 c.f.s

Submerged Orifice with Adjustable Opening.—In certain irrigated sections the head available for water measurement is so small that a combination headgate and measuring device is necessary. Such devices are called submerged orifice headgates. Due to contraction conditions and to the edge of the opening the flow through a standard submerged orifice is less than the flow through a submerged orifice headgate for equal-sized opening and equal head[18]. The discharge through an orifice headgate is variable, depending

[18]The coefficient "C" in the formula, $Q = 8.02\ CA\ (H)^{\frac{1}{2}}$ for the type of submerged orifice headgates, was found by Wadsworth, as reported in California Agricultural Experiment Station Circular 250 (1922), to vary from 0.68 to 0.8 as compared to 0.61 for the standard submerged orifice.

upon the way the opening is constructed. It is, therefore, impractical to compute tables of general application.

If an adjustable orifice headgate is calibrated, i.e., the discharge is determined for each size opening and each different head, it becomes a convenient and reasonably accurate measuring device and remains so as long as it is maintained in its original condition. An engineer familiar with water measurement should be employed to calibrate the gate and develop the discharge table for it.

RATING FLUMES

On many streams the steep slopes, gravel, and debris make the use of weirs or orifices impracticable. Such streams may be measured by constructing a rating flume and calibrating it by determining the relationship between the discharge and the depth of water in the flume. The rating is made by measuring the discharge with a current meter. The services of a competent engineer should be sought to rate the flume. The flume should be so located that the water enters parallel to the axis of the flume and in such a position that the depth of water in the flume is not affected by backwater or diversions immediately above or below the structure. If properly constructed and calibrated, the rating flume is a fairly accurate device for measuring water. Once the device is calibrated the discharge can be determined by reading the gage placed in the flume. If conditions affecting the relationship between gage height and discharge change, the flume must be re-rated.

IMPROVED VENTURI FLUMES

The two most serious disadvantages in the use of weirs are: (1) The collecting of sediment above the weir (this also applies to the submerged orifice) and (2) the requirement of appreciable fall or drop in the water surface which prohibits their use in localities having but little fall. The rating flume described above has been used to a great extent and has proved fairly satisfactory, but it must be rated with a current meter, and the relationship between gage height and discharge is subject to change with a difference in channel conditions.

The Improved Venturi Flume[19] possesses characteristics which obviate many of the objections to the weir, orifice, rating flume, or other devices which are now in general use. Extensive tests and field observations made at the Colorado Experiment Station and at Cornell University show that for free flow, the discharge may be determined by a single gage reading. Figure 14 shows the Improved Venturi Flume and stilling-well with float indicating tape. Briefly, the Improved Venturi Flume consists of a box which may be made of wood, concrete, or metal, a level floor with a converging section and vertical side walls. At the end of the converging section the floor slopes downward 9 inches in 2 feet. The outlet section is 3

[19]Parshall, R. L. "The Improved Venturi Flume". Colo. Agr. Exp. Sta. Bul. 336 (1928)

feet long and diverges. The floor of the outlet rises 6 inches in 3 feet. The lower end of the outlet is 3 inches lower than the crest. Figure 14 and Table 9 show the standard dimensions and capacities of the Improved Venturi Flume.

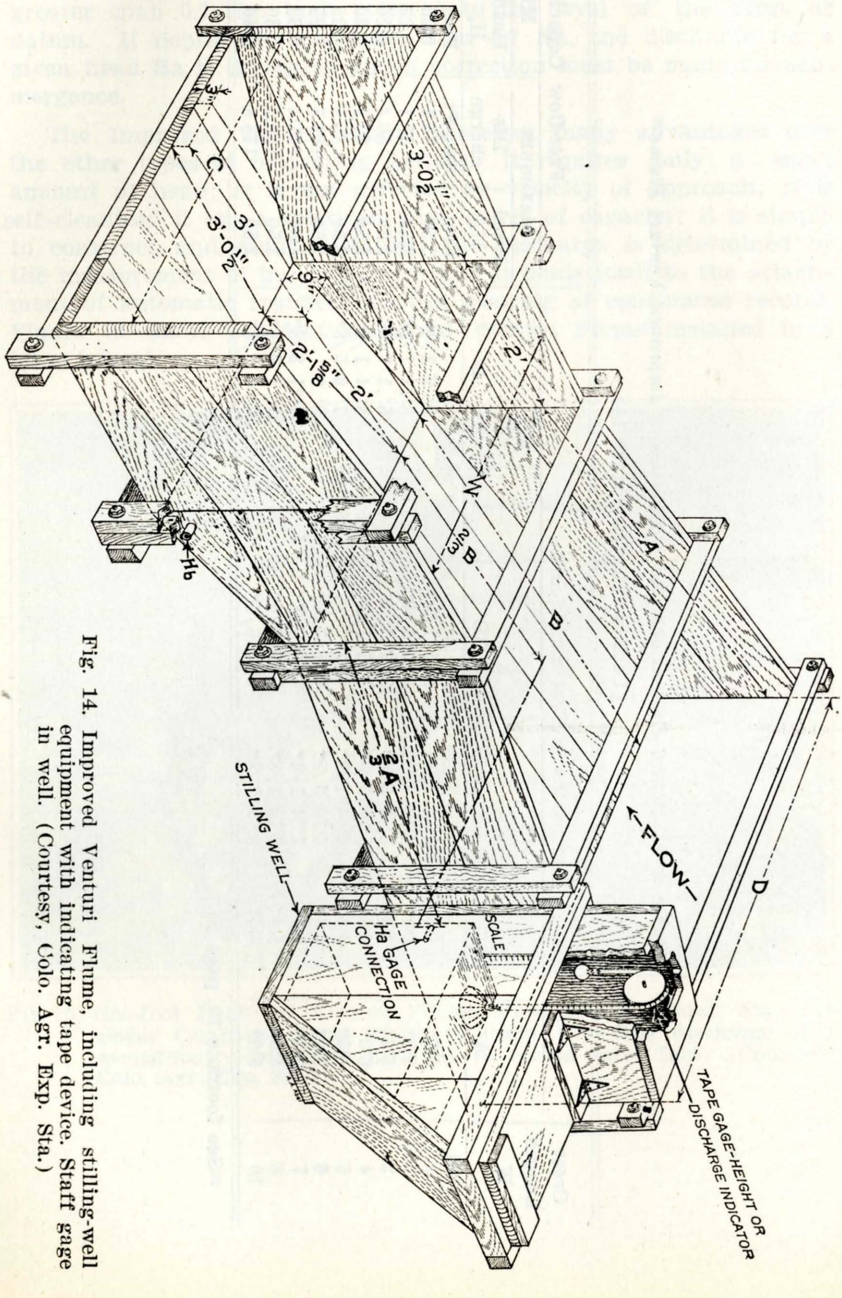

Fig. 14. Improved Venturi Flume, including stilling-well equipment with indicating tape device. Staff gage in well. (Courtesy, Colo. Agr. Exp. Sta.)

Table 9.—Standard Dimensions and Capacities of Improved Venturi Flume[20]

(Letters refer to Figure 14)

Crest Length W	Dimensions in Feet and Inches						Free-flow Capacity			
							Maximum		Minimum	
	A	2/3A	B	2/3B	C	D	Head H_a	Dis-charge	Head H_a	Dis-charge
Feet							Feet	Sec.-Ft.	Feet	Sec.-Ft.
1	4′6″	3′0″	4′ 4 7/8″	2′11 1/4″	2	2′ 9 1/4″	2.50	16.1	0.20	0.35
2	5′0″	3′4″	4′10 7/8″	3′ 3 1/4″	3	3′11 1/2″	2.50	33.1	0.20	0.66
3	5′6″	3′8″	5′ 4 3/4″	3′ 7 1/8″	4	5′ 1 7/8″	2.50	50.4	0.20	0.97
4	6′0″	4′0″	5′10 5/8″	3′11 1/8″	5	6′ 4 1/4″	2.50	67.9	0.20	1.26
5	6′6″	4′4″	6′ 4 1/2″	4′ 3″	6	7′ 6 5/8″	2.50	85.6	0.25	2.22
6	7′0″	4′8″	6′10 3/8″	4′ 6 7/8″	7	8′ 9″	2.50	103.5	0.25	2.63
7	7′6″	5′0″	7′ 4 1/4″	4′10 7/8″	8	9′11 3/8″	2.50	121.4	0.30	4.08
8	8′0″	5′4″	7′10 1/8″	5′ 2 3/4″	9	11′ 1 3/4″	2.50	139.5	0.30	4.62
10	9′0″	6′0″	8′ 9 7/8″	5′10 5/8″	11	13′ 6 3/8″	2.50	175.8	0.40	9.10

[20]See footnote 19, page 28.

The head is measured at a point 2/3 B (Fig. 14) from the crest. The head may be measured on a weir scale placed on the side of the flume, or even better in a stilling-well attached to the side of flume.

To insure conditions of free flow, the head Hb should not be greater than 0.7 Ha; both referred to the level of the crest as datum. If depth Hb is greater than 0.7 Ha, the discharge for a given head Ha is decreased and a correction must be made for submergence.

The Improved Venturi Flume possesses many advantages over the other types of measuring devices. It requires only a small amount of head; it is not affected by velocity of approach; it is self-cleaning; it has a relatively high range of capacity; it is simple to construct and easily installed; the discharge is determined by the measurement of but one head; and it lends itself to the attachment of automatic registers for the securing of continuous records. Figure 15 shows a 1-foot Improved Venturi Flume installed in a farm lateral.

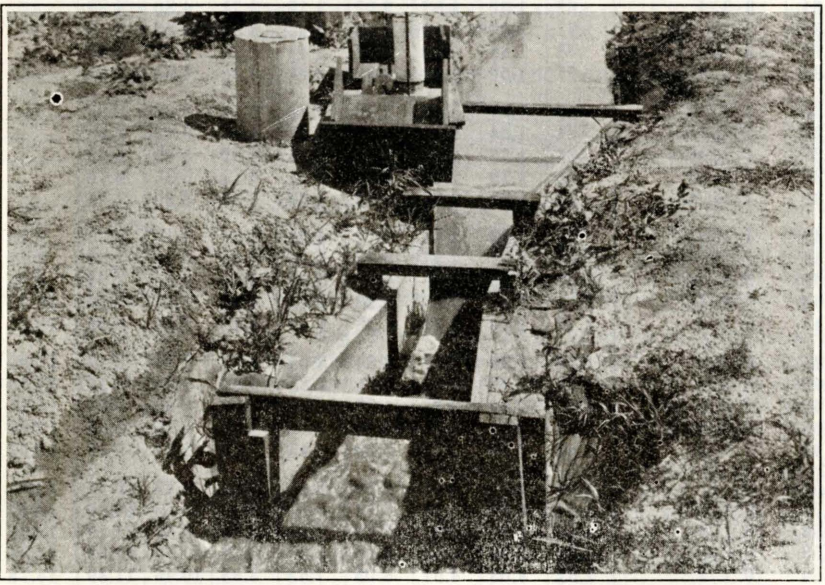

Fig. 15. One-foot Improved Venturi Flume, Experimental Farm, American Sugar Company, Rocky Ford, Colorado. Free-flow discharge of 1 second-foot. Instrument installed to record total flow. (Courtesy, Colo. Agr. Exp. Sta.)

Table 10.—Free-flow discharge for Improved Venturi Flume[21]

Computed from the formula $Q = 4\,W\,H_a^{1.522\,W^{0.026}}$

Upper Head H_a		Discharge per second for flumes of various throat widths								
		1 Foot	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	7 Feet	8 Feet	10 Feet
		Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.
0.20	2 3/8	0.35	0.66	0.97	1.26	....	....	....	....	....
.21	2 1/2	.37	.71	1.04	1.36	....	....	....	....	....
.22	2 5/8	.40	.77	1.12	1.47	....	....	....	....	....
.23	3 3/4	.43	.82	1.20	1.58	....	....	....	....	....
.24	2 7/8	.46	.88	1.28	1.69	....	....	....	....	....
.25	3	.49	.93	1.37	1.80	2.22	2.63	....	....	....
.26	3 1/8	.51	.99	1.46	1.91	2.36	2.80	....	....	....
.27	3 1 4	.54	1.05	1.55	2.03	2.50	2.97	....	....	....
.28	3 3/8	.58	1.11	1.64	2.15	2.65	3.15	....	....	....
.29	3 1/2	.61	1.18	1.73	2.27	2.80	3.33	....	....	....
.30	3 5/8	.64	1.24	1.82	2.39	2.96	3.52	4.08	4.62	....
.31	3 3/4	.68	1.30	1.92	2.52	3.12	3.71	4.30	4.88	....
.32	3 13/16	.71	1.37	2.02	2.65	3.28	3.90	4.52	5.13	....
.33	3 15/16	.74	1.44	2.12	2.78	3.44	4.10	4.75	5.39	....
.34	4 1/16	.77	1.50	2.22	2.92	3.61	4.30	4.98	5.66	....
.35	4 3/16	.80	1.57	2.32	3.06	3.78	4.50	5.22	5.93	....
.36	4 5/16	.84	1.64	2.42	3.19	3.95	4.71	5.46	6.20	....
.37	4 7/16	.88	1.72	2.53	3.34	4.13	4.92	5.70	6.48	....
.38	4 9/16	.92	1.79	2.64	3.48	4.31	5.13	5.95	6.76	....
.39	4 11/16	.95	1.86	2.75	3.62	4.49	5.35	6.20	7.05	....
.40	4 13/16	.99	1.93	2.86	3.77	4.68	5.57	6.46	7.34	9.10
.41	4 15/16	1.03	2.01	2.97	3.92	4.86	5.80	6.72	7.64	9.47
.42	5 1/16	1.07	2.09	3.08	4.07	5.05	6.02	6.98	7.94	9.85
.43	5 3/16	1.11	2.16	3.20	4.22	5.24	6.25	7.25	8.24	10.23
.44	5 1/4	1.15	2.24	3.32	4.38	5.43	6.48	7.52	8.55	10.61
.45	5 3/8	1.19	2.32	3.44	4.54	5.63	6.72	7.80	8.87	11.00
.46	5 1/2	1.23	2.40	3.56	4.70	5.83	6.96	8.08	9.19	11.40
.47	5 5/8	1.27	2.48	3.68	4.86	6.03	7.20	8.36	9.51	11.81
.48	5 3/4	1.31	2.57	3.80	5.03	6.24	7.44	8.65	9.84	12.22
.49	5 7/8	1.35	2.65	3.92	5.20	6.45	7.69	8.94	10.17	12.63
.50	6	1.39	2.73	4.05	5.36	6.66	7.94	9.23	10.51	13.05
.51	6 1/8	1.44	2.82	4.18	5.53	6.87	8.20	9.53	10.85	13.47
.52	6 1/4	1.48	2.90	4.31	5.70	7.09	8.46	9.83	11.19	13.90
.53	6 3/8	1.52	2.99	4.44	5.88	7.30	8.72	10.14	11.54	14.34
.54	6 1/2	1.57	3.08	4.57	6.05	7.52	8.98	10.45	11.89	14.78
.55	6 5/8	1.62	3.17	4.70	6.23	7.74	9.25	10.76	12.24	15.22
.56	6 3/4	1.66	3.26	4.84	6.41	7.97	9.52	11.07	12.60	15.67
.57	6 13/16	1.70	3.35	4.98	6.59	8.20	9.79	11.39	12.96	16.13
.58	6 15/16	1.75	3.44	5.11	6.77	8.43	10.07	11.71	13.33	16.59
.59	7 1/16	1.80	3.53	5.25	6.96	8.66	10.35	12.03	13.70	17.05
.60	7 3/16	1.84	3.62	5.39	7.15	8.89	10.63	12.36	14.08	17.52
.61	7 5/16	1.88	3.72	5.53	7.34	9.13	10.92	12.69	14.46	17.99
.62	7 7/16	1.93	3.81	5.68	7.53	9.37	11.20	13.02	14.84	18.47
.63	7 9/16	1.98	3.91	5.82	7.72	9.61	11.49	13.36	15.23	18.96
.64	7 11/16	2.03	4.01	5.97	7.91	9.85	11.78	13.70	15.62	19.45

[21] See footnote 19, page 28.

Table 10—(Continued)

Upper Head		Discharge per second for flumes of various throat widths								
	H_a	1 Foot	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	7 Feet	8 Feet	10 Feet
		Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.
.65	7 13/16	2.08	4.11	6.12	8.11	10.10	12.08	14.05	16.01	19.94
.66	7 15/16	2.13	4.20	6.26	8.31	10.34	12.38	14.40	16.41	20.44
.67	8 1/16	2.18	4.30	6.41	8.51	10.59	12.68	14.75	16.81	20.94
.68	8 3/16	2.23	4.40	6.56	8.71	10.85	12.98	15.10	17.22	21.45
.69	8 1/4	2.28	4.50	6.71	8.91	11.10	13.28	15.46	17.63	21.96
.70	8 3/8	2.33	4.60	6.86	9.11	11.36	13.59	15.82	18.04	22.48
.71	8 1/2	2.38	4.70	7.02	9.32	11.62	13.90	16.18	18.45	23.00
.72	8 5/8	2.43	4.81	7.17	9.53	11.88	14.22	16.55	18.87	23.52
.73	8 3/4	2.48	4.91	7.33	9.74	12.14	14.53	16.92	19.29	24.05
.74	8 7/8	2.53	5.02	7.49	9.95	12.40	14.85	17.29	19.71	24.59
.75	9	2.58	5.12	7.65	10.16	12.67	15.17	17.66	20.14	25.13
.76	9 1/8	2.63	5.23	7.81	10.38	12.94	15.49	18.04	20.57	25.67
.77	9 1/4	2.68	5.34	7.97	10.60	13.21	15.82	18.42	21.01	26.22
.78	9 3/8	2.74	5.44	8.13	10.81	13.48	16.15	18.81	21.46	26.77
.79	9 1/2	2.80	5.55	8.30	11.03	13.76	16.48	19.20	21.91	27.33
.80	9 5/8	2.85	5.66	8.46	11.25	14.04	16.81	19.59	22.36	27.89
.81	9 3/4	2.90	5.77	8.63	11.48	14.32	17.15	19.99	22.81	28.46
.82	9 13/16	2.96	5.88	8.79	11.70	14.60	17.49	20.39	23.26	29.03
.83	9 15/16	3.02	6.00	8.96	11.92	14.88	17.83	20.79	23.72	29.60
.84	10 1/16	3.07	6.11	9.13	12.15	15.17	18.17	21.18	24.18	30.18
.85	10 3/16	3.12	6.22	9.30	12.38	15.46	18.52	21.58	24.64	30.76
.86	10 5/16	3.18	6.33	9.48	12.61	15.75	18.87	21.99	25.11	31.35
.87	10 7/16	3.24	6.44	9.65	12.84	16.04	19.22	22.40	25.58	31.94
.88	10 9/16	3.29	6.56	9.82	13.07	16.33	19.57	22.82	26.06	32.53
.89	10 11/16	3.35	6.68	10.00	13.31	16.62	19.93	23.24	26.54	33.13
.90	10 13/16	3.41	6.80	10.17	13.55	16.92	20.29	23.66	27.02	33.74
.91	10 15/16	3.46	6.92	10.35	13.79	17.22	20.65	24.08	27.50	34.35
.92	11 1/16	3.52	7.03	10.53	14.03	17.52	21.01	24.50	27.99	34.96
.93	11 3/16	3.58	7.15	10.71	14.27	17.82	21.38	24.93	28.48	35.57
.94	11 1/4	3.64	7.27	10.89	14.51	18.13	21.75	25.36	28.97	36.19
.95	11 3/8	3.70	7.39	11.07	14.76	18.44	22.12	25.79	29.47	36.82
.96	11 1/2	3.76	7.51	11.26	15.00	18.75	22.49	26.22	29.97	37.45
.97	11 5/8	3.82	7.63	11.44	15.25	19.06	22.86	26.66	30.48	38.08
.98	11 3/4	3.88	7.75	11.63	15.50	19.37	23.24	27.10	30.98	38.72
.99	11 7/8	3.94	7.88	11.82	15.75	19.68	23.62	27.55	31.49	39.36
1.00	12	4.00	8.00	12.00	16.00	20.00	24.00	28.00	32.00	40.00
1.01	12 1/8	4.06	8.12	12.19	16.25	20.32	24.38	28.45	32.52	40.65
1.02	12 1/4	4.12	8.25	12.38	16.51	20.64	24.77	28.90	33.04	41.30
1.03	12 3/8	4.18	8.38	12.57	16.76	20.96	25.16	29.36	33.56	41.96
1.04	12 1/2	4.25	8.50	12.70	17.02	21.28	25.55	29.82	34.08	42.62
1.05	12 5/8	4.31	8.63	12.96	17.28	21.61	25.94	30.28	34.61	43.28
1.06	12 3/4	4.37	8.76	13.15	17.54	21.94	26.34	30.74	35.14	43.95
1.07	12 13/16	4.43	8.88	13.34	17.80	22.27	26.74	31.20	35.68	44.62
1.08	12 15/16	4.50	9.01	13.54	18.07	22.60	27.13	31.67	36.22	45.30
1.09	13 1/16	4.56	9.14	13.74	18.34	22.93	27.53	32.14	36.76	45.98

Table 10—(Continued)

Upper Head		Discharge per second for flumes of various throat widths								
H_a		1 Foot	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	7 Feet	8 Feet	10 Feet
		Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.
1.10	13 3/16	4.62	9.27	13.93	18.60	23.26	27.94	32.62	37.30	46.66
1.11	13 5/16	4.68	9.40	14.13	18.86	23.60	28.35	33.10	37.84	47.35
1.12	13 7/16	4.75	9.54	14.33	19.13	23.94	28.76	33.58	38.39	48.04
1.13	13 9/16	4.82	9.67	14.53	19.40	24.28	29.17	34.06	38.94	48.73
1.14	13 11/16	4.88	9.80	14.73	19.67	24.62	29.58	34.54	39.50	49.43
1.15	13 13/16	4.94	9.94	14.94	19.94	24.96	30.00	35.02	40.06	50.13
1.16	13 15/16	5.01	10.07	15.14	20.22	25.31	30.41	35.51	40.62	50.84
1.17	14 1/16	5.08	10.20	15.34	20.50	25.66	30.83	36.00	41.18	51.55
1.18	14 3/16	5.15	10.34	15.55	20.78	26.01	31.25	36.50	41.75	52.27
1.19	14 1/4	5.21	10.48	15.76	21.05	26.36	31.68	37.00	42.32	52.99
1.20	14 3/8	5.28	10.61	15.96	21.33	26.71	32.10	37.50	42.89	53.71
1.21	14 1/2	5.34	10.75	16.17	21.61	27.06	32.53	38.00	43.47	54.43
1.22	14 5/8	5.41	10.89	16.38	21.90	27.42	32.96	38.50	44.05	55.16
1.23	14 3/4	5.48	11.03	16.60	22.18	27.78	33.39	39.00	44.64	55.89
1.24	14 7/8	5.55	11.17	16.81	22.47	28.14	33.82	39.51	45.22	56.63
1.25	15	5.62	11.31	17.02	22.75	28.50	34.26	40.02	45.80	57.37
1.26	15 1/8	5.69	11.45	17.23	23.04	28.86	34.70	40.54	46.38	58.11
1.27	15 1/4	5.76	11.59	17.44	23.33	29.22	35.14	41.05	46.97	58.86
1.28	15 3/8	5.82	11.73	17.66	23.62	29.59	35.58	41.57	47.57	59.61
1.29	15 1/2	5.89	11.87	17.88	23.92	29.96	36.02	42.09	48.17	60.36
1.30	15 5/8	5.96	12.01	18.10	24.21	30.33	36.47	42.62	48.78	61.12
1.31	15 3/4	6.03	12.16	18.32	24.50	30.70	36.92	43.14	49.38	61.88
1.32	15 13/16	6.10	12.30	18.54	24.80	31.07	37.37	43.67	49.99	62.65
1.33	15 15/16	6.18	12.44	18.76	25.10	31.44	37.82	44.20	50.60	63.42
1.34	16 1/16	6.25	12.59	18.98	25.39	31.82	38.28	44.73	51.22	64.19
1.35	16 3/16	6.32	12.74	19.20	25.69	32.20	38.74	45.26	51.84	64.96
1.36	16 5/16	6.39	12.89	19.42	25.99	32.58	39.20	45.80	52.46	65.74
1.37	16 7/16	6.46	13.03	19.64	26.30	32.96	39.66	46.35	53.08	66.52
1.38	16 9/16	6.53	13.18	19.87	26.60	33.34	40.12	46.89	53.70	67.31
1.39	16 11/16	6.60	13.33	20.10	26.90	33.72	40.58	47.44	54.33	68.10
1.40	16 13/16	6.68	13.48	20.32	27.21	34.11	41.05	47.99	54.95	68.90
1.41	16 15/16	6.75	13.63	20.55	27.52	34.50	41.52	48.54	55.58	69.70
1.42	17 1/16	6.82	13.78	20.78	27.82	34.89	41.99	49.09	56.22	70.50
1.43	17 3/16	6.89	13.93	21.01	28.14	35.28	42.46	49.64	56.86	71.30
1.44	17 1/4	6.97	14.08	21.24	28.45	35.67	42.94	50.20	57.50	72.11
1.45	17 3/8	7.04	14.23	21.27	28.76	36.06	43.42	50.76	58.14	72.92
1.46	17 1/2	7.12	14.38	21.70	29.07	36.46	43.89	51.32	58.78	73.73
1.47	17 5/8	7.19	14.54	21.94	29.38	36.86	44.37	51.88	59.43	74.55
1.48	17 3/4	7.26	14.69	22.17	29.70	37.26	44.26	52.45	60.08	75.37
1.49	17 7/8	7.37	14.85	22.41	30.02	37.66	45.34	53.02	60.74	76.19
1.50	18	7.41	15.00	22.64	30.34	38.06	45.82	53.59	61.40	77.02
1.51	18 1/8	7.49	15.16	22.88	30.66	38.46	46.31	54.16	62.06	77.85
1.52	18 1/4	7.57	15.31	23.12	30.98	38.87	46.80	54.74	62.72	78.69
1.53	18 3/8	7.64	15.47	23.36	31.30	39.28	47.30	55.32	63.38	79.53
1.54	18 1/2	7.72	15.62	23.60	31.63	39.68	47.79	55.90	64.04	80.37

Table 10—(Continued)

Upper Head		Discharge per second for flumes of various throat widths								
	H_a	1 Foot	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	7 Feet	8 Feet	10 Feet
		Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.
1.55	18 5/8	7.80	15.78	23.84	31.95	40.09	48.28	56.48	64.71	81.21
1.56	18 3/4	7.87	15.94	24.08	32.27	40.51	48.78	57.06	65.38	82.06
1.57	18 13/16	7.95	16.10	24.32	32.60	40.92	49.28	57.65	66.06	82.91
1.58	18 15/16	8.02	16.26	24.56	32.93	41.35	49.78	58.24	66.74	83.77
1.59	19 1/16	8.10	16.42	24.80	33.26	41.75	50.28	58.83	67.42	84.63
1.60	19 3/16	8.18	16.58	25.05	33.59	42.17	50.79	59.42	68.10	85.49
1.61	19 5/16	8.26	16.74	25.30	33.92	42.59	51.30	60.02	68.79	86.36
1.62	19 7/16	8.34	16.90	25.54	34.26	43.01	51.81	60.62	69.48	87.23
1.63	19 9/16	8.42	17.06	25.79	34.60	43.43	52.32	61.22	70.17	88.10
1.64	19 11/16	8.49	17.22	26.04	34.93	43.86	52.83	61.82	70.86	88.97
1.65	19 13/16	8.57	17.38	26.29	35.26	44.28	53.34	62.42	71.56	89.85
1.66	19 15/16	8.65	17.55	26.54	35.60	44.70	53.86	63.03	72.26	90.73
1.67	20 1/16	8.73	17.72	26.79	35.94	45.13	54.38	63.64	72.96	91.62
1.68	20 3/16	8.81	17.88	27.04	36.28	45.56	54.90	64.25	73.66	92.51
1.69	20 1/4	8.89	18.04	27.30	36.62	46.00	55.42	64.86	74.37	93.40
1.70	20 3/8	8.97	18.21	27.55	36.96	46.43	55.95	65.48	75.08	94.29
1.71	20 1/2	9.05	18.38	27.80	37.30	46.86	56.48	66.10	75.79	95.19
1.72	20 5/8	9.13	18.54	28.06	37.65	47.30	57.00	66.72	76.50	96.09
1.73	20 3/4	9.21	18.71	28.32	38.00	47.74	57.53	67.34	77.22	96.99
1.74	20 7/8	9.29	18.88	28.57	38.34	48.17	58.06	67.96	77.94	97.90
1.75	21	9.38	19.04	28.82	38.69	48.61	58.60	68.59	78.66	98.81
1.76	21 1/8	9.46	19.21	29.08	39.04	49.05	59.13	69.22	79.38	99.72
1.77	21 1/4	9.54	19.38	29.34	39.39	49.50	59.67	69.85	80.10	100.6
1.78	21 3/8	9.62	19.55	29.60	39.74	49.94	60.20	70.48	80.83	101.5
1.79	21 1/2	9.70	19.72	29.87	40.10	50.38	60.74	71.11	81.56	102.4
1.80	21 5/8	9.79	19.90	30.13	40.45	50.83	61.29	71.75	82.29	103.4
1.81	21 3/4	9.87	20.07	30.39	40.80	51.28	61.83	72.39	83.03	104.4
1.82	21 13/16	9.95	20.24	30.65	41.16	51.73	62.38	73.03	83.77	105.3
1.83	21 15/16	10.04	20.42	30.92	41.52	52.18	62.92	73.68	84.51	106.2
1.84	22 1/16	10.12	20.59	31.18	41.88	52.64	63.46	74.33	85.25	107.1
1.85	22 3/16	10.20	20.76	31.45	42.24	53.09	64.01	74.98	86.00	108.1
1.86	22 5/16	10.29	20.93	31.71	42.60	53.55	64.57	75.63	86.75	109.0
1.87	22 7/16	10.38	21.10	31.98	42.96	54.00	65.13	76.28	87.50	110.0
1.88	22 9/16	10.46	21.28	32.25	43.32	54.46	65.69	76.93	88.25	110.9
1.89	22 11/16	10.54	21.46	32.52	43.69	54.92	66.25	77.58	89.00	111.9
1.90	22 13/16	10.62	21.63	32.79	44.05	55.39	66.81	78.24	89.76	112.9
1.91	22 15/16	10.71	21.81	33.06	44.42	55.85	67.37	78.90	90.52	113.8
1.92	23 1/16	10.80	21.99	33.33	44.79	56.32	67.93	79.56	91.29	114.8
1.93	23 3/16	10.88	22.17	33.60	45.16	56.78	68.50	80.23	92.05	115.8
1.94	23 1/4	10.97	22.35	33.87	45.53	57.25	69.06	80.90	92.82	116.7
1.95	23 3/8	11.06	22.53	34.14	45.90	57.72	69.63	81.57	93.59	117.7
1.96	23 1/2	11.14	22.70	34.42	46.27	58.19	70.20	82.24	94.36	118.7
1.97	23 5/8	11.23	22.88	34.70	46.64	58.67	70.78	82.91	95.14	119.7
1.98	23 3/4	11.31	23.06	34.97	47.02	59.14	71.35	83.58	95.92	120.6
1.99	23 7/8	11.40	23.24	35.25	47.40	59.61	71.92	84.26	96.70	121.6

Table 10—(Continued)

Upper Head	H_a	Discharge per second for flumes of various throat widths								
		1 Foot	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	7 Feet	8 Feet	10 Feet
		Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. f.t
2.00	24	11.49	23.43	35.53	47.77	60.08	72.50	84.94	97.48	122.6
2.01	24 1/8	11.58	23.61	35.81	48.14	50.56	73.08	85.62	98.26	123.6
2.02	24 1/4	11.66	23.79	36.09	48.52	61.04	73.66	86.30	99.05	124.6
2.03	24 3/8	11.75	23.98	36.37	48.90	61.52	74.24	86.99	99.84	125.6
2.04	24 1/2	11.84	24.16	36.65	49.29	62.00	74.83	87.68	100.6	126.6
2.05	24 5/8	11.93	24.34	36.94	49.67	62.48	75.42	88.37	101.4	127.6
2.06	24 3/4	12.02	24.52	37.22	50.05	62.97	76.00	89.06	102.2	128.6
2.07	24 13/16	12.10	24.70	37.50	50.44	63.46	76.59	89.75	103.0	129.6
2.08	24 15/16	12.19	24.89	37.78	50.82	63.94	77.19	90.44	103.8	130.6
2.09	25 1/16	12.28	25.08	38.06	51.21	64.43	77.78	91.14	104.6	131.6
2.10	25 3/16	12.37	25.27	38.35	51.59	64.92	78.37	91.84	105.4	132.7
2.11	25 5/16	12.46	25.46	38.64	51.98	65.41	78.97	92.54	106.2	133.7
2.12	25 7/16	12.55	25.64	38.93	52.37	65.91	79.56	93.25	107.0	134.7
2.13	25 9/16	12.64	25.83	39.22	52.76	66.40	80.15	93.95	107.9	135.7
2.14	25 11/16	12.73	26.01	39.50	53.15	66.89	80.75	94.66	108.7	136.8
2.15	25 13/16	12.82	26.20	39.79	53.54	67.39	81.36	95.37	109.5	137.8
2.16	25 15/16	12.92	26.39	40.08	53.94	67.89	81.97	96.08	110.3	138.8
2.17	26 1/16	13.01	26.58	40.37	54.34	68.39	82.58	96.79	111.1	139.9
2.18	26 3/16	13.10	26.77	40.66	54.73	68.89	83.19	97.51	111.9	140.9
2.19	26 1/4	13.19	26.96	40.96	55.12	69.39	83.80	98.23	112.8	142.0
2.20	26 3/8	13.28	27.15	41.25	55.52	69.90	84.41	98.94	113.6	143.0
2.21	26 1/2	13.37	27.34	41.54	55.92	70.40	85.02	99.66	114.4	144.1
2.22	26 5/8	13.46	27.54	41.84	56.32	70.90	85.63	100.0	115.3	145.1
2.23	26 3/4	13.56	27.73	42.13	56.72	71.41	86.25	101.1	116.1	146.2
2.24	26 7/8	13.65	27.92	42.43	57.12	71.92	86.87	101.8	116.9	147.3
2.25	27	13.74	28.12	42.73	57.52	72.43	87.49	102.6	117.8	148.3
2.26	27 1/8	13.84	28.31	43.02	57.93	72.94	88.11	103.3	118.6	149.4
2.27	27 1/4	13.93	28.50	43.32	58.34	73.46	88.73	104.0	119.5	150.5
2.28	27 3/8	14.02	28.70	43.62	58.74	73.97	89.35	104.8	120.3	151.5
2.29	27 1/2	14.12	28.90	43.92	59.15	74.49	89.98	105.5	121.2	152.6
2.30	27 5/8	14.21	29.09	44.22	59.56	75.01	90.61	106.2	122.0	153.7
2.31	27 3/4	14.30	29.29	44.52	59.96	75.52	91.24	107.0	122.9	154.8
2.32	27 13/16	14.40	29.49	44.83	60.37	76.04	91.87	107.7	123.7	155.8
2.33	27 15/16	14.49	29.69	45.13	60.79	76.57	92.50	108.5	124.6	156.9
2.34	28 1/16	14.59	29.89	45.43	61.20	77.09	93.14	109.2	125.4	158.0
2.35	28 3/16	14.68	30.08	45.74	61.61	77.61	93.77	110.0	126.3	159.1
2.36	28 5/16	14.78	30.28	46.04	62.03	78.13	94.41	110.7	127.2	160.2
2.37	28 7/16	14.87	30.48	46.35	62.44	78.66	95.05	111.5	128.0	161.3
2.38	28 9/16	14.97	30.69	46.66	62.86	79.19	95.69	112.2	128.9	162.4
2.39	28 11/16	15.07	30.89	46.96	63.27	79.72	96.33	113.0	129.8	163.5
2.40	28 13/16	15.16	31.09	47.27	63.69	80.25	96.97	113.7	130.7	164.6
2.41	28 15/16	15.26	31.29	47.58	64.11	80.78	97.62	114.5	131.5	165.7
2.42	29 1/16	15.35	31.49	47.89	64.53	81.31	98.27	115.3	132.4	166.8
2.43	29 3/16	15.45	31.68	48.20	64.95	81.84	98.91	116.0	133.3	168.0
2.44	29 1/4	15.55	31.89	48.51	65.38	82.38	99.56	116.8	134.2	169.1

Table 10—(Concluded)

Upper Head		Discharge per second for flumes of various throat widths								
H_a		1 Foot	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	7 Feet	8 Feet	10 Feet
		Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. f.t
2.45	29 3/8	15.64	32.10	48.82	65.80	82.92	100.2	117.6	135.1	170.2
2.46	29 1/2	15.74	32.30	49.13	66.23	83.45	100.9	118.3	135.9	171.3
2.47	29 5/8	15.89	32.50	49.45	66.65	83.99	101.5	119.1	136.8	172.4
2.48	29 3/4	15.94	32.70	49.76	67.07	84.54	102.2	119.9	137.7	173.6
2.49	29 7/8	16.03	32.90	50.08	67.50	85.07	102.8	120.6	138.6	174.7
2.50	30	16.13	33.11	50.39	67.93	85.62	103.5	121.4	139.5	175.8

Measure of Discharge.—To determine the discharge through an Improved Venturi Flume, read the head on the gage and enter the table with the gage reading in inches or feet. Follow to the right and intersect the column headed with the width of flume in question. The figure at the intersection is the discharge in cubic feet per second.

Example: Ha=0.3. Width=2 feet
Q=1.24 c.f.s.

VOLUME METERS

During recent years many mechanical devices to measure water have been designed. These devices not only measure the rate of flow but most of them automatically register the total amount of water passing in any period of time. In addition to the devices which measure the water, which for the most part are volume meters, there are many types of automatic water-stage registers which record the level of the water surface; and when used in connection with weirs, orifices, rating flumes, or Improved Venturi Flumes they furnish a continuous record of rate of flow and total discharge.

The most important among the volume meters are the following: Dethridge meter, Grant-Mitchell meter, Hill meter, Hanna meter, Reliance meter, and Lyman water register. The first four meters are fully described in California Agricultural Experiment Station Bulletin No. 247[22]. The last two are fully described in any manufacturer's catalog. Colorado Agricultural Experiment Station Bulletin 215[23] contains a report of complete investigations on the Dethridge meter.

Automatic water stage registers used in connection with rating stations, flumes, weirs, and orifices are used wherever a continuous record is required. These devices record the height of water level. There are two types of registers. In one type the clock operates the drum on which is placed the record sheet and the float which rides

[22]See footnote 17, page 26.
[23]Cone, V. M. "The Dethridge Meter". Colo. Agr. Exp. Sta. Bul. 215 (1915)

on the water surface operates the pencil which records on the sheet. In the other type the clock operates the pencil and the float the revolving drum. Water stage registers are manufactured in various sizes and to different scales. Some will operate only one week without attention, while others will operate for 90 days. If a continuous record is needed a competent engineer should be employed to select the proper measuring and recording device and to make the installation.

DIVISORS

Many irrigation companies in Utah divide their streams according to the number of shares of stock owned by individual or groups of individuals. On the smaller streams a single company either owns the entire flow or it is divided among two or three companies, each company owning a share of the total stream. The users are not so much interested in the measurement of the water as they are in the division of the stream. For example, one company may be entitled to five-twelfths of the stream and another company to seven-twelfths of the stream. The two companies own all the water in the stream. They are not particularly interested in the quantity, but they are interested in the division. Many times a division must be made where it is impractical to make a measurement.

If even an approximate division is made, there are a few principles which must be ovserved. The water must approach the divider in parallel paths, i.e., there must be no cross currents. To secure

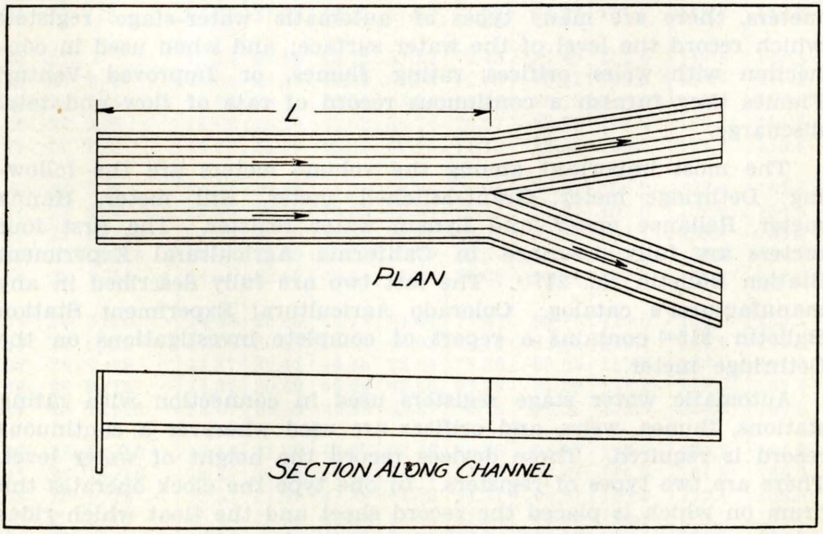

Fig. 16. Typical divider used on streams carrying considerable gravel

this condition the divider box must be placed at the lower end of a long flume or of a straight open channel. The floor of the channel immediately above the divider should be level transversely. If the water is reasonably free from silt it is desirable to have the water approach the divider at a low velocity. For streams carrying considerable silt and gravel there should be no obstruction in the channel in form of bulkhead, and the velocity with which the water enters should be maintained through the structure. Figure 16 shows a form of divider used on mountain streams which carry considerable debris. It is very important that these structures have a long straight channel of approach and that the floor be level transversely. Any gravel or debris allowed to collect in the channel of approach will cause cross currents and interfere with proper division.

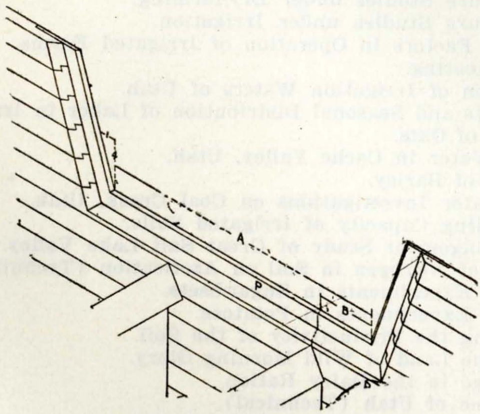

Fig. 17. Divider below trapezoidal weir

The flow over a weir can be easily divided by placing a sharp-edged partition below the weir to divide the stream as it falls over the crest. The crest of this partition should be placed a sufficient distance below the weir crest to permit a free circulation of air between the divider and the sheet of water falling over the weir.

The discharge over a weir is not exactly proportional to the length of the crest; the error in considering it so, however, is slight. The trapezoidal weir is the most desirable form if it is to be used as a divider. The flow over this weir is very nearly proportional to length of crest. If it is desired to divide the stream into two parts, one taking five-sixths and the other one-sixth of the flow, the divider should be placed one-sixth of the distance from the end of the weir. Figure 17 shows a trapezoidal weir divider fixed to divide a stream into three parts.

If it is desired to divide a stream into two equal parts, the rectangular weir, either with or without end contractions, is entirely satisfactory.

LIST OF AVAILABLE BULLETINS

121—Soil of Southern Experiment Station.
122—Nature of the Dry Farm Soil of Utah.
128—Blooming Periods and Yields of Fruit in Relation to Minimum Temperatures.
132—Minor Dry-land Crops at Nephi Experiment Farm.
134—Nitric Nitrogen Content of Country Rock.
137—Quality of Home-grown Wheat vs. Imported Wheat.
139—Movement of Soluble Salts with Soil Moisture.
141—Variation in Minimum Temperatures due to Topography of a Mountain Valley in Relation to Fruit-growing.
143—Fruit Treet Root System—Spread and Depth.
144—Water Table Variations—Causes and Effects.
147—Alkali Content of Irrigation Waters.
150—Further Studies on Nitric Nitrogen Content of Country Rock.
152—Effect of Soil Moisture on Certain Factors in Wheat Production.
158—Soil Moisture Studies under Dry-farming.
159—Soil Moisture Studies under Irrigation.
160—Important Factors in Operation of Irrigated Farms.
161—Orchard Heating.
163—Composition of Irrigation Waters of Utah.
165—Labor Costs and Seasonal Distribution of Labor in Irrigated Crops.
167—Irrigation of Oats.
173—Duty of Water in Cache Valley, Utah.
178—Irrigation of Barley.
181—Duty-of-Water Investigations on Coal Creek, Utah.
183—Water-holding Capacity of Irrigated Soils.
184—Farm Management Study of Great Salt Lake Valley.
185—Influence of Nitrogen in Soil on Azofication (Technical).
186—Irrigation Experiments in Sugar-beets.
187—Irrigation Experiments in Potatoes.
188—Maintaining the Productivity of the Soil.
189—Ridding the Land of Wild Morning Glory.
190—Corn Silage in the Dairy Ration.
191—Oedipodinae of Utah (Technical).
192—Biennial Report of Director, 1923 and 1924.
193—Cache County Water Conservation District No. 1.
194—The Influence of Storage on the Composition of Flour (Technical)
195—Field Studies of Sugar-beet Nematode.
196—Fruit Tree Leaf Roller.
197—The Pear Leaf Blister Mite as an Apple Pest.
198—Report of Director (for 18-month Period from Jan. 1, 1925 to June 30, 1926).
199—Mutual Irrigation Companies in Utah.
200—Maintaining Potato Yields by Hill Selection.
201—Economic Insects in Some Streams of Northern Utah.
202—Some Observations on Winter Injury in Utah Peach Orchards.
203—Cattle Ranching in Utah.
204—Sheep Ranching in Utah.
205—The Beet Leaf Hopper in Utah.
206—Treehopper Injury in Utah Orchards.
207—The Physical Curd Character of Milk and Its Relation to the Digestibility and Food Value of Milk for Infants.
208—An Economic Study of the Apple Industry of Utah, 1926 and 1927.
209—Biennial Report of Experiment Station, 1926-28.
210—The Mineral Contents of Grains.
211—Silage Corn Varieties for Utah.